Water Plant Optimization Study

COMMUNITY OF ODESSA WATER TREATMENT PLANT

November 1991

Environment Canada
Environnement Canada

92-06715/

ISBN 0-7729-8933-8

WATER PLANT OPTIMIZATION STUDY

COMMUNITY OF ODESSA
WATER TREATMENT PLANT

Project No. 7-2047

Report prepared for:
Drinking Water Section
Water Resources Branch
Ontario Ministry of the Environment

Report prepared by:
R.B. Hunsinger and K.J. Roberts
Water Resources Branch
in association with
CH2M Hill Engineering Limited

NOVEMBER 1991

Cette publication technique
n'est disponible qu'en anglais.

Copyright: Queen's Printer for Ontario, 1991
This publication may be reproduced for non-commercial purposes
with appropriate attribution.

PIBS 1734
log 91-2302-228

Study conducted by:

George Zukovs and Debrah Ross

of

CH2M HILL ENGINEERING LIMITED

Under the direction of the Project Committee:

Ron Hunsinger - MOE Water Resources Branch
W.G. Spencer - MOE Southeastern Region
John Bishop - MOE Southeastern Region
Bill Gregson - MOE Project Engineering Branch
Janusz Budziakowski - MOE Environmental Approvals Branch

Address all correspondence to:

MInistry of the Environment
Water Resources Branch
1 St. Clair Avenue West, 4th Floor
Toronto, Ontario
M4V 1K6

Please note that some of the recommendations contained in this report may have already been completed at time of publication. For more information, please contact the local municipality, or the Water Resources Branch of the Ministry of the Environment.

CONTENTS

			Page
INTRODUCTION			1
A.	RAW WATER		3
	A.1	Source	3
	A.2	Quality	3
B.	FLOW MEASUREMENT		6
C.	PROCESS COMPONENTS		7
	C.1	General	7
	C.2	Design Data	12
		C.2.a Capacity	12
	C.3	Process Component Inventory	12
		C.3.a Intake	12
		C.3.b Low Lift Pumping	13
		C.3.c Chemical Addition and Flash Mixing	13
		C.3.d Reactor Clarifier	14
		C.3.e Sand Filters	17
		C.3.f Filtered Water Pumping	21
		C.3.g Granular Activated Carbon Contactor	21
		C.3.h Wastewater Equalization Tank	24
		C.3.i Clearwell	24
	C.4	Chemical Systems	25
		C.4.a Settling Aid	25
		C.4.b Coagulant	25
		C.4.c Coagulant Aid	26
		C.4.d Disinfection	26
	C.5	Sampling	27
	C.6	Plates	28
D.	PLANT OPERATION		39
	C.1	General Description	39
	D.2	Flow Control	40
	D.3	Operation of Specific Components	40
		D.3.a Intake	40
		D.3.b Low Lift Pumps	40
		D.3.c Flash Mixing	41
		D.3.d Flocculation and Clarification	41
		D.3.e Sand Filters	42
		D.3.f Filtered Water Pumping	43
		D.3.g Granular Activated Carbon Contactor	43
		D.3.h Clearwell	44

CONTENTS (cont'd)

			Page
	D.4	Chemicals Used in Particulate Removal	44
	D.5	Disinfection	46
	D.6	Sampling and Data Collection	47
		D.6.a In-Plant Monitoring	47
		D.6.b Routine Sampling	49
	D.7	Operator Duties	49
E.		PLANT PERFORMANCE	50
	E.1	Flow Control	50
		E.1.a Reactor Clarifier	50
		E.1.b Filters and GAC Contactors	52
		E.1.c Alternatives for Flow Control	52
		E.1.d Summary of Recommendations	53
	E.2	Turbidity and Colour Removal	54
		E.2.a Historical Performance	55
		E.2.b Chemicals for Coagulation	56
		E.2.c Chemical Application Points and Rapid Mixing	58
		E.2.d Coagulation, Flocculation and Settling	59
		E.2.e Sand Filters	61
		E.2.f GAC Contactors	62
		E.2.g Summary of Recommendations	64
	E.3	Taste and Odour Removal	65
		E.3.a Dioxin/Furan Compounds Detected on GAC Media	65
		E.3.b GAC Contactor Process Control	67
		E.3.c Summary of Recommendations	68
	E.4	Disinfection	68
		E.4.a Historical Performance	68
		E.4.b Pre-chlorination	69
		E.4.c Post-chlorination	70
		E.4.d Process Control	71
		E.4.e Total Trihalomethanes	71
		E.4.f Summary of Recommendations	72
	E.5	Raw Water	73
		E.5.a Extent of Problem	73
		E.5.b Alternatives to Control Hydrogen Sulphide and D.O. Problems	73
		E.5.c Summary of Recommendations	75

CONTENTS (cont'd)

			Page
E.6	Other		75
	E.6.a	Flow Monitoring	75
	E.6.b	Routine Monitoring of Plant Operational Data	75
	E.6.c	Laboratory	75
	E.6.d	Operating Staff	76
F.	SUMMARY OF RECOMMENDATIONS		77
F.1	Studies		77
F.2	Equipment or Process Modifications or Expenditures		78
F.3	Operational Changes		79
REFERENCES			80

Appendixes

I Physical and Chemical Water Quality Parameters-Particulate Removal Summaries for Odessa Water Treatment Plant

II Bacteriological Water Quality Data for Odessa WTP

III Summary of Flows for Odessa WTP

IV Disinfection Summaries for Odessa WTP

V Jar Testing Protocol

TABLES

		Page
C-1	Details of In-Plant Sampling Lines	27
D-1	In-Plant Sampling and Analysis Program at Odessa WTP	47
D-2	Summary of Routine Sampling Programs at Odessa WTP	49
E-1	Summary of Treated Water Colour Levels at Odessa WTP	55
E-2	Summary of Treated Water Turbidities at Odessa WTP	55
E-3	Jar Testing Results for Odessa WTP Raw Water	57
E-4	Summary of Total Chlorine Residual Concentrations in Odessa WTP Filtered Water, Treated Water and Distribution System	69

FIGURES

		Page
A-1	Odessa WTP Raw Water Intake Location	4
C-1	Odessa Water Treatment Plant Process Flow Schematic	8
C-2	Block Design Summary Schematic of Odessa WTP	9
C-3	Odessa WTP, Available Piping and Process Diagram	10
C-4	Plan of Odessa WTP Site	11
C-5	Schematic of Reactor Clarifier at Odessa WTP	15
C-6	Schematic of Sand Filter at Odessa WTP	19
C-7	Schematic of the Granular Activated Carbon Contactor at Odessa WTP	23
D-1	Daily In-Plant Monitoring Sheet Used at Odessa WTP	48

INTRODUCTION

The Ontario Ministry of the Environment (MOE) has established a Drinking Water Surveillance Program (DWSP) for the purpose of providing an up to date database of the quality of drinking water from Ontario Water Treatment Plants (WTPs). In conjunction with DWSP, a specific plant investigation and process and operational evaluation is required for each water treatment plant involved in the program. Consequently, the MOE sponsored "Water Treatment Plant Optimization Studies" are being undertaken for each WTP in order to document the existing water quality, to define the present unit processes and operating conditions and to determine an optimum treatment strategy for contaminant removal at the plant. Specifically, emphasis has been placed on the particulate removal and disinfection efficiency of the water treatment plant.

A detailed protocol for the "WTP Optimization Studies" has been prepared by MOE. The Odessa WTP Optimization Study has been prepared in accordance with the protocol.

This report presents the Odessa WTP raw water quality data, describes the uni treatment processes and outlines present plant operating methodologies. The final sections of this report present an evaluation of the current particulate removal, disinfection and taste and odour control practices and to recommend the modifications necessary to optimize plant performance.

The report has been organized into the following 6 sections:

Section A: Raw Water Source

This section presents the historical physical, chemical and biological quality data for the raw water.

Section B: Flow Measurement

Methods of measuring plant flows are presented in this section.

Section C: Process Components

This section contains descriptions of all of the process components at the plant.

Section D: Plant Operation

This section presents the of present methods of operating the treatment plant in general terms and with respect to each of the process components.

Section E: Plant Performance

This section presents a review of the historical plant performance, in terms of flow control, effluent quality, disinfection and other affecting factors. Recommendations are also presented to optimize performance.

Section F: Summary of Recommendations

A summary of the recommendations to optimize plant performance is contained in section F.

In addition, Appendices are included which contain historical (1985-1987) water quality data, particulate removal profiles, disinfection summaries and DWSP (1988) analytical results for the Odessa WTP.

A. RAW WATER

A.1 SOURCE

The Township of Ernestown Community of Odessa Water Treatment Plant (WTP) uses water from Millhaven Creek, a small channel which passes through Town and discharges into the North Channel of Lake Ontario at Millhaven. The WTP intake draws water 200 m upstream from the Odessa Water Pollution Control Plant discharge outlet. Figure A-1 shows a map of the WTP and intake locations.

Millhaven Creek has a long-term history of insufficient water quantity problems. In order to supply enough water to the WTP, the Creek was dammed to create a reservoir for water storage. The MOE has an agreement with the Cataraqui Regional Conservation Authority to operate the dam in order to maintain sufficient water in the reservoir for WTP demand, and also sufficient flow down stream of the dam to meet minimum flow requirements for WPCP discharge and supply downstream rural water users. In the past, especially in dry years, there have been several complaints about water quantity from downstream users. In addition, the community serviced by the Odessa WTP have been subject to lawn watering restrictions. In order to solve the quantity problems, the MOE is planning a detailed hydrologic study of the Millhaven Creek so that methods to improve the supply of water to meet all requirements may be identified.

The Millhaven Creek reservoir is very shallow which causes some water quality concerns. In the winter, the reservoir becomes anaerobic, resulting in severe taste and odour levels. In the summer, water temperatures become quite high and a large number of beavers use the reservoir, causing a risk of fecal contamination of the supply, and a particular concern of Giardia lambia cysts.

A.2 QUALITY

Appendix I presents a summary of the physical and chemical raw water quality for the years 1985 to 1987, based on measurements recorded at the plant (Table I-1). Presented in Table I-2 are highlights of seasonal variations for the selected parameters. Table I-3 presents the Drinking Water Sampling Program (DWSP) results for the WTP for the period from February to November 1988.

Selected raw water quality parameters have historically varied as follows:

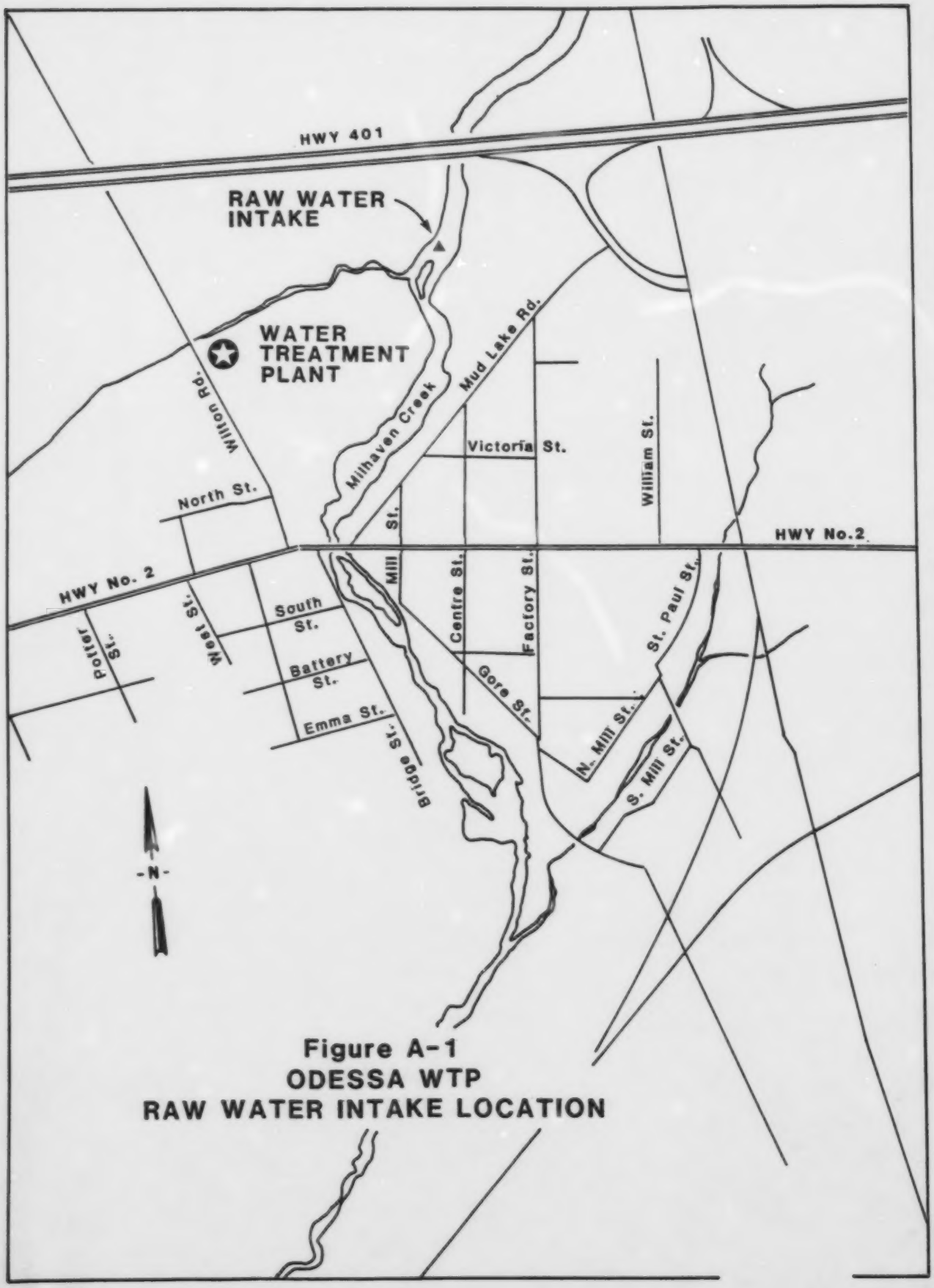


Figure A-1
ODESSA WTP
RAW WATER INTAKE LOCATION

Parameter	1985-1987	DWSP (1988)
Turbidity (FTU) (field)	0.4 - 2.5	0.65 - 2.1
Colour (TCU)	5 - 24	13.5 - 29.5
Temperature (°C)	2 - 25	1 - 21
Alkalinity (mg/L as $CaCO_3$)	-	103.9 - 172.0
Hardness (mg/L as $CaCO_3$	-	115.0 - 192.0
pH (field)	7.5 - 8.5	7.3 - 7.8
Aluminum (µg/L)	-	6.4 - 34.0

Contrary to what is expected based on the raw water source, turbidity and colour levels are fairly low. In the past 3-1/2 years, turbidity levels have varied from 0.4 FTU to 2.5 FTU with little seasonal variation in evidence. The colour level in raw water ranged from 5 to 29.5 TCU but typically fell in the range of 5 to 15 TCU. Colour levels are at highest in July to October, and are at minimum in the January to March period.

DWSP results from analyses of trace organics and heavy metals showed that manganese levels exceeded 0.05 mg/L in 1 of the 6 samples in 1988. All other metals and all trace organics were never detected above Ontario Drinking Water Objective levels. Only 8 out of 83 trace organics were ever detected above the DWSP minimum detection limits for these contaminants in 1988 samples.

Table II-1 presents the bacteriological raw water quality parameters for 1985 to 1987. Table II-2 presents bacteriological data from the DWSP results for February to July 1988. There has been no marked seasonal variation in total and fecal coliform. The historical bacteriological raw water quality varies as follows:

Bacteria	1985-1987	DWSP (1988)
Total Coliform	80% of samples: 6-100 mL 20% of samples: >100/100 mL	6-2100/100 mL
Fecal Coliform	70% of samples: 6-10/100 mL 30% of samples: >10/100 mL	1-19/100 mL

Historically, the Odessa WTP has had problems with the raw water source. In winter months, the creek freezes over, causing the raw water to become anoxic or anaerobic. Potential problems associated with these conditions are the absence of dissolved oxygen, the presence of hydrogen sulphide, and elevated iron and manganese levels.

Dissolved oxygen and sulphides have not been measured historically in raw water and therefore the extent of the problem is unknown.

B. FLOW MEASUREMENT

At the Odessa Water Treatment Plant only the treated water flows to the distribution system are monitored continuously. The flow metering equipment has the following characteristics:

Location:	High lift discharge line
Type:	Magnetic flow meter with DC pick-up
Capacity:	4.5 ML/d
Manufacturer:	Fisher Porter
Display:	Circular chart & totalizer (Displays flows in m^3)

Flow metering equipment is calibrated annually by the MOE Technical Services Unit in Kingston. No adjustment was necessary at the last calibration in July 1988.

The raw water flow is calculated daily based on the treated water flow added to the volume of flow exiting as wastewater, including sand filter and GAC contactor backwash water. An estimated volume of 10 m^3 is used for each sand filter backwash, and the number of backwashes each day is recorded automatically on a totalizer. The volume of GAC contactor backwash wastewater is estimated at a rate of 2.2 m^3/min. The total backwash volume is obtained by multiplying the flow rate by the backwash cycle time. The volume of water that is wasted as clarifier sludge is not considered in the raw water calculations. The following equation shows the raw water flow calculation:

Daily Raw Water Flow Volume	=	Treated Water Volume	+	Sand Filter Backwash Volume	+ Carbon Contactor Backwash Volume

It should be noted that raw water flow volumes calculated using this method are approximate. In addition, although the wastewater volume has historically been calculated daily, it was not always added to the treated water volume to find the raw water volume. In these cases, raw water volumes were assumed equal to treated water volumes.

C. PROCESS COMPONENTS

C.1 GENERAL

The Odessa Water Treatment Plant was built in 1975, with a treatment system that originally included the following processes: coagulation, flocculation, clarification and disinfection. In order to overcome an unexpected flavour problem in the finished water, the S.E. Regional MOE Operations, with the assistance of the MOE Drinking Water Section, performed numerous plant scale tests to determine the optimum water treatment required for taste and odour removal. The testing involved:

i) Aeration - at the intake
ii) Addition of Potassium Permanganate
iii) Superchlorination
iv) Powdered Activated Carbon (PAC)
v) Pilot Columns - GAC evaluation

Other than PAC and GAC, these tests were not successful in the removal of the taste and odour compounds. The plant used PAC addition to raw water but the dosage of PAC required was in excess of 20 mg/L which created too heavy a load on the filters. Therefore, in 1979 the PAC treatment was eliminated and in addition to a number of other improvements at the plant, a granular activated carbon contactor was included for taste and odour control of treated water. Both the original plant and expansion designs were prepared by Chisholm Fleming and Associates, Scarborough, Ontario. A process flow schematic of the plant is presented in Figure C-1.

Chlorine gas is used for disinfection at the plant, and is added to both the raw and treated water. Alum is employed as the prime coagulant and a commercial polyelectrolyte and bentonite clay are used as coagulant aids.

The low lift pumps that convey water through the flocculation, clarification and filtration processes operate intermittently and automatically depending on the water level in the treated water clearwells. The filtered water pumps that convey water through the GAC contactor and to the clearwell operate intermittently and automatically depending on the water level in an intermediate filtered water well.

Treated water from the plant is conveyed by high lift pumps to the Town distribution system and water storage tower. The high lift pumps operate intermittently and automatically depending on the water level in the tower.

A block schematic of the Odessa WTP that summarizes the design information for each treatment process is presented in Figure C-2. A schematic of the main piping and processes is presented in Figure C-3. A plan of the Odessa WTP layout is presented in Figure C-4.

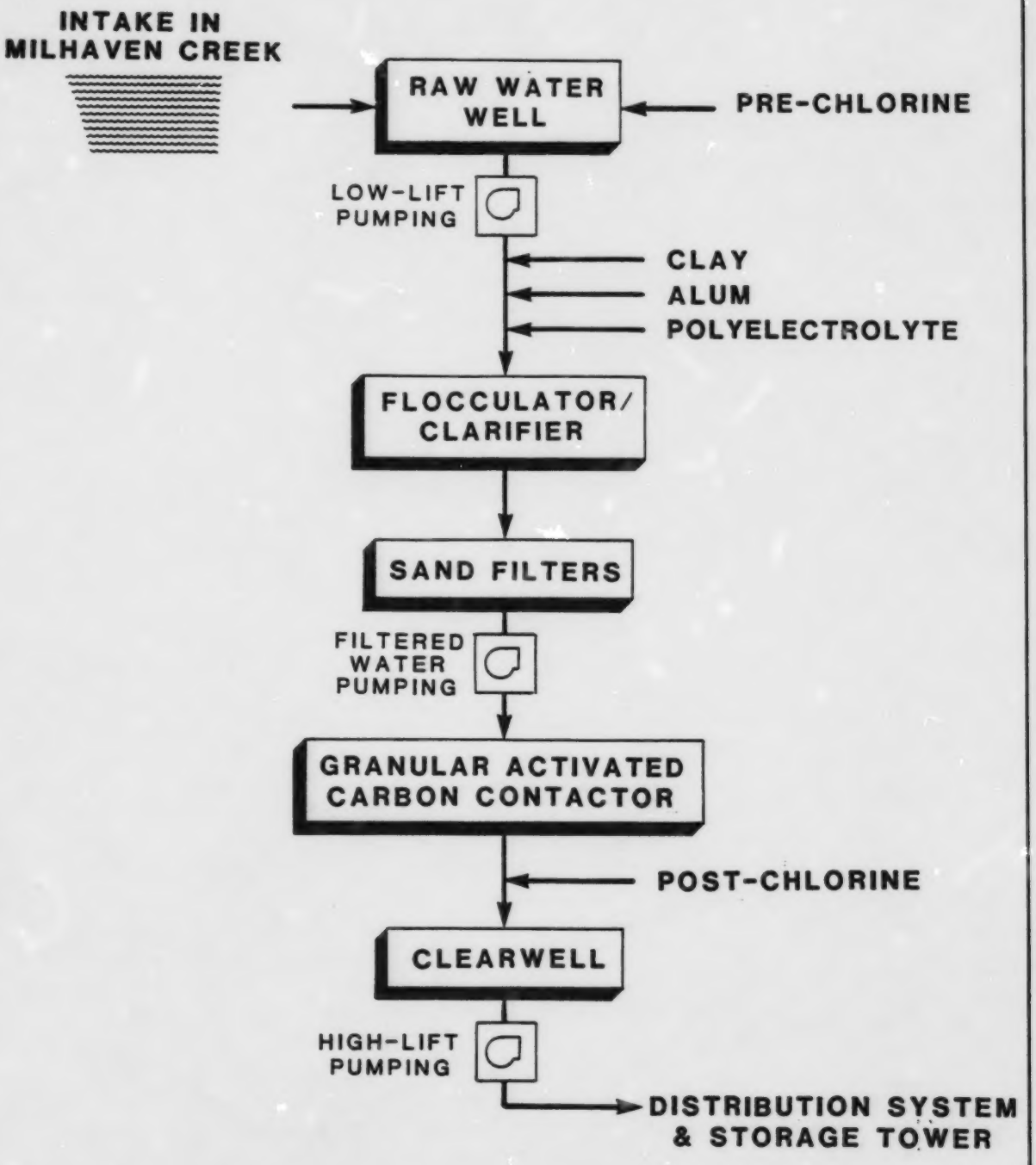


Figure C-1

ODESSA WATER TREATMENT PLANT
PROCESS FLOW SCHEMATIC

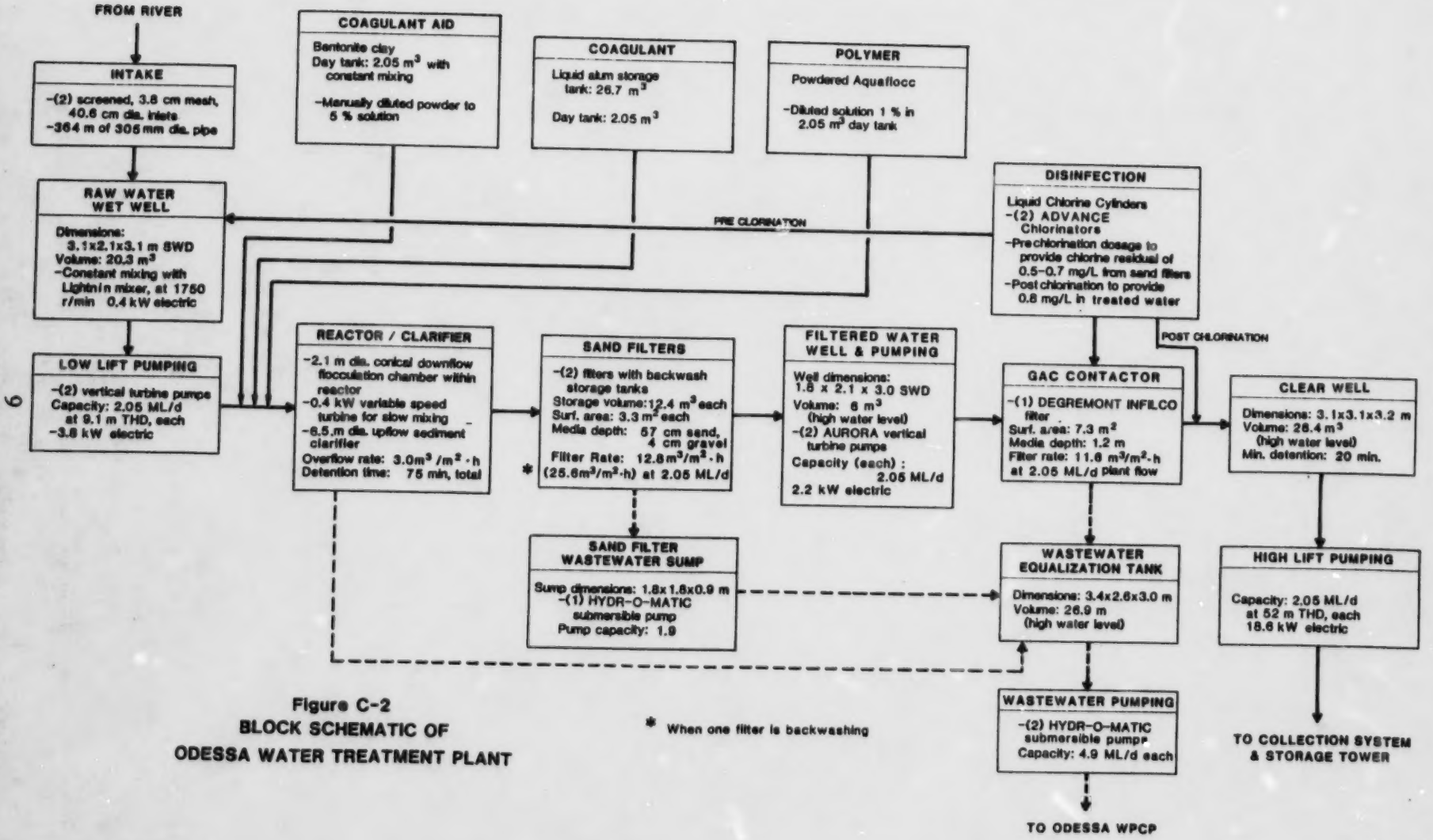

FROM RIVER
INTAKE
-(2) screened, 3.8 cm mesh, 40.6 cm dia. inlets
-364 m of 305 mm dia. pipe
COAGULANT AID
Bentonite clay
Day tank: 2.05 m3 with constant mixing
-Manually diluted powder to 5 % solution
COAGULANT
Liquid alum storage tank: 26.7 m3
Day tank: 2.05 m3
POLYMER
Powdered Aquafloc
-Diluted solution 1 % in 2.05 m3 day tank
DISINFECTION
Liquid Chlorine Cylinders
-(2) ADVANCE Chlorinators
-Prechlorination dosage to provide chlorine residual of 0.5-0.7 mg/L from sand filters
-Post chlorination to provide 0.8 mg/L in treated water
PRE CLORINATION
POST CHLORINATION
RAW WATER WET WELL
Dimensions: 3.1x2.1x3.1 m SWD
Volume: 20.3 m3
-Constant mixing with Lightnin mixer, at 1750 r/min 0.4 kW electric
LOW LIFT PUMPING
-(2) vertical turbine pumps
Capacity: 2.05 ML/d at 9.1 m THD, each
-3.8 kW electric
REACTOR / CLARIFIER
-2.1 m dia. conical downflow flocculation chamber within reactor
-0.4 kW variable speed turbine for slow mixing
-6.5 m dia. upflow sediment clarifier
Overflow rate: 3.0m3 /m2 · h
Detention time: 75 min, total
SAND FILTERS
-(2) filters with backwash storage tanks
Storage volume: 12.4 m3 each
Surf. area: 3.3 m2 each
Media depth: 57 cm sand, 4 cm gravel
Filter Rate: 12.8 m3/m2 · h
(25.6m3/m2·h) at 2.05 ML/d
*
FILTERED WATER WELL & PUMPING
Well dimensions: 1.8 x 2.1 x 3.0 SWD
Volume: 6 m3 (high water level)
-(2) AURORA vertical turbine pumps
Capacity (each) : 2.05 ML/d
2.2 kW electric
GAC CONTACTOR
-(1) DEGREMONT INFILCO filter
Surf. area: 7.3 m2
Media depth: 1.2 m
Filter rate: 11.6 m3/m2·h at 2.05 ML/d plant flow
CLEAR WELL
Dimensions: 3.1x3.1x3.2 m
Volume: 28.4 m3 (high water level)
Min. detention: 20 min.
SAND FILTER WASTEWATER SUMP
Sump dimensions: 1.8x1.8x0.9 m
-(1) HYDR-O-MATIC submersible pump
Pump capacity: 1.9
WASTEWATER EQUALIZATION TANK
Dimensions: 3.4x2.6x3.0 m
Volume: 26.9 m (high water level)
HIGH LIFT PUMPING
Capacity: 2.05 ML/d at 52 m THD, each
18.6 kW electric
WASTEWATER PUMPING
-(2) HYDR-O-MATIC submersible pumps
Capacity: 4.9 ML/d each
TO COLLECTION SYSTEM & STORAGE TOWER
TO ODESSA WPCP

Figure C-2
BLOCK SCHEMATIC OF
ODESSA WATER TREATMENT PLANT

* When one filter is backwashing

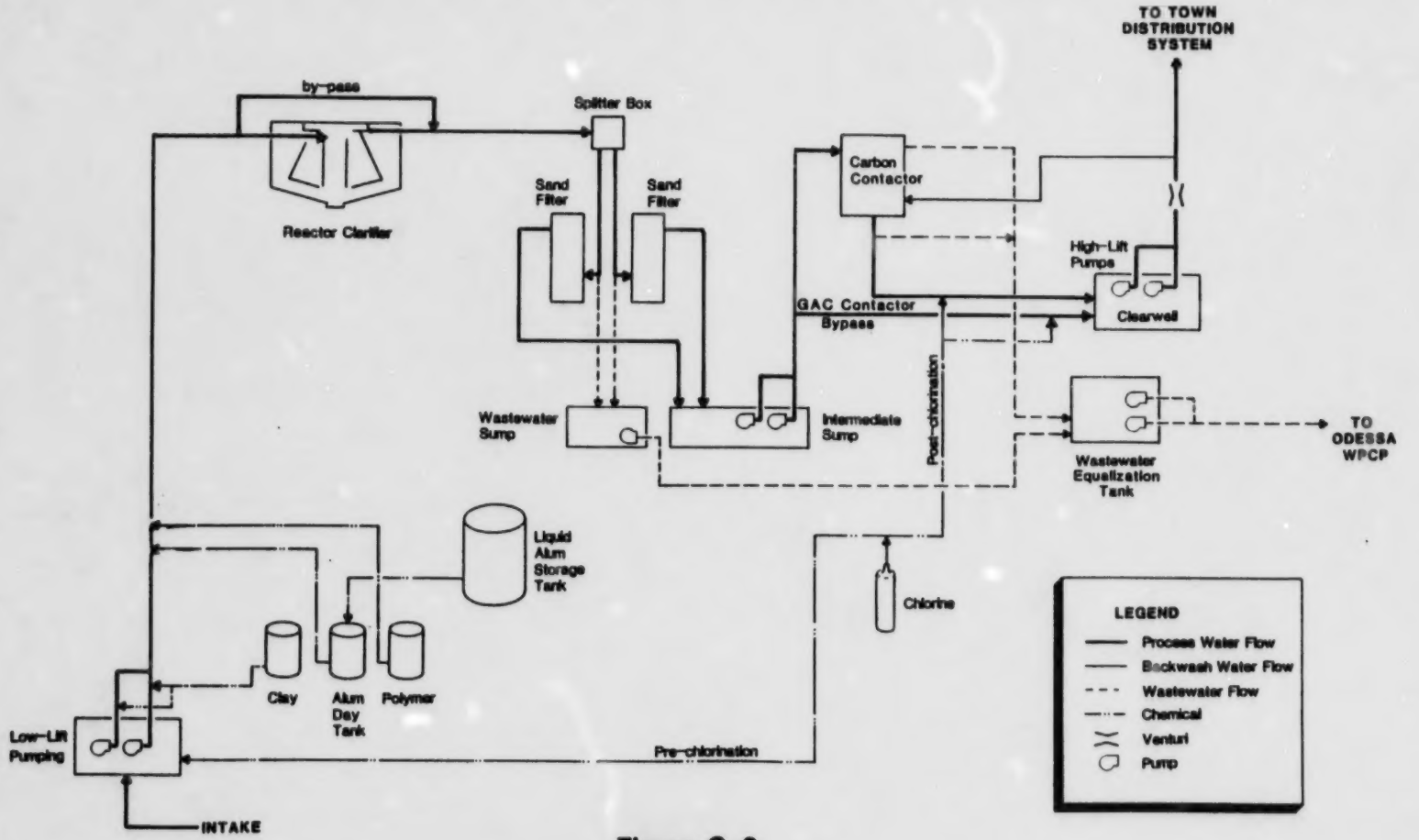


Figure C-3
ODESSA WTP,
AVAILABLE PIPING AND PROCESS DIAGRAM

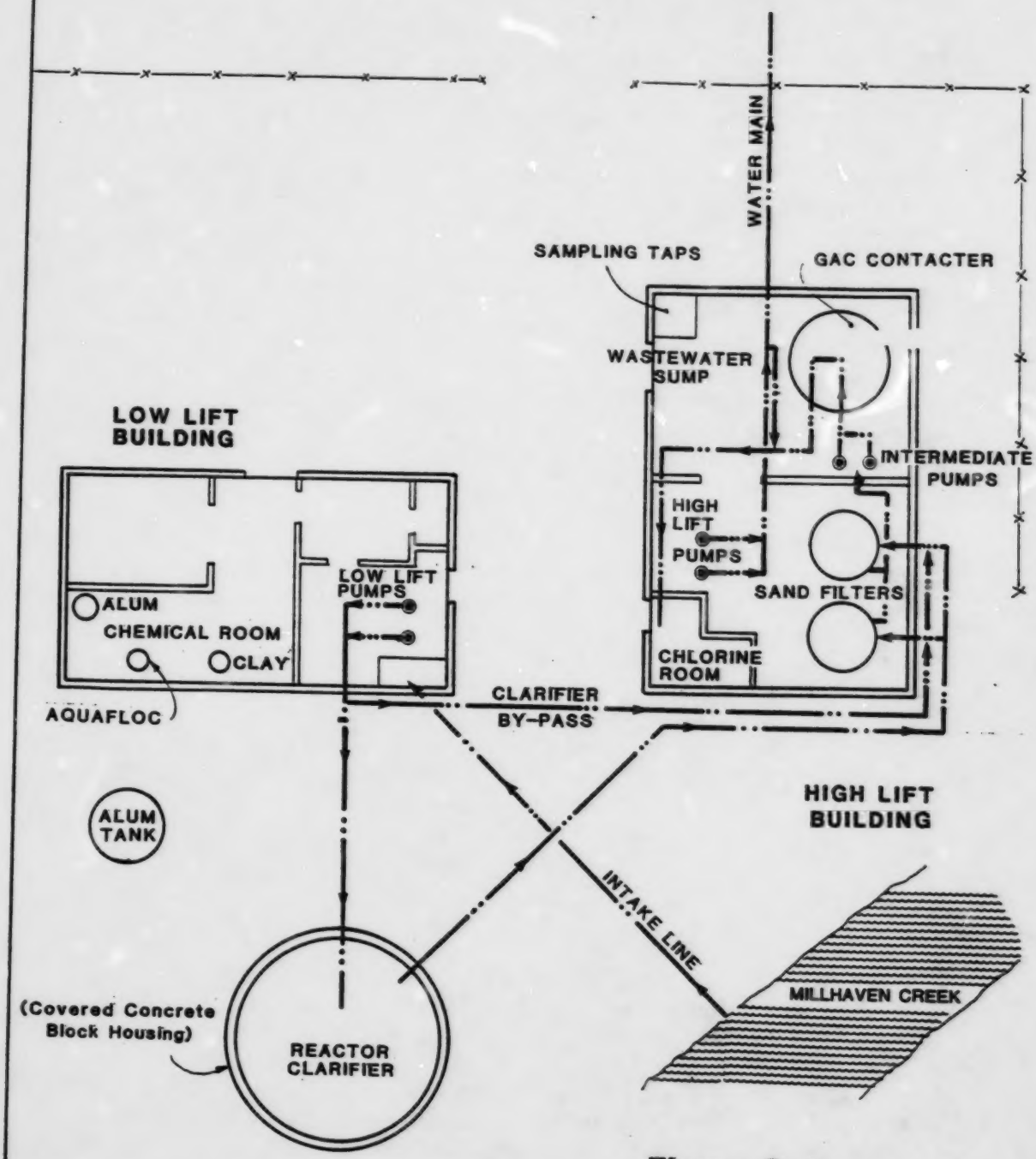


Figure C-4
PLAN OF ODESSA WTP SITE

C.2 DESIGN DATA

C.2.a Capacity

The Odessa WTP was designed to treat 2.05 ML/d, according to the MOE Certificate of Approval. The average daily raw and treated water flows for the three year period 1985 to 1987 are presented in Appendix III (Table III-1). For this period, the maximum daily treated water flow was 2.00 ML/d or 98 percent of the rated design capacity. This flow rate is not consistent with the rated capacity, since about 5 to 10 percent of the total raw water flow is wasted. This implies that either the low lift pumps were operating at greater than their rated capacity or that the flow meter was not properly calibrated. Typically, flows ranged from 0.5 to 1.2 ML/d, or 24 to 59 percent of the total plant rated design capacity.

It should be noted that the raw water flow volumes summarized in Table 1 generally are equal to the treated water volumes. This is because wastewater volumes, although calculated, were not always added to the treated water volumes to arrive at the actual raw water volume during the study period.

In this three year period, the Odessa WTP provided water for an average community population of 973. An additional population of approximately 1500 were serviced for about 7 hours per day in Odessa schools. Assuming that the per capita water demand at the schools is one third of the per capita community demand, the average demand in this period was 545 L/cap.d. This value is within a typical range for a non-industrial domestic community.

When in operation, the low lift and intermediate pumping rates are constant and equal to the plant design capacity of 2.05 ML/d. The firm capacity of the Odessa WTP is 2.05 ML/d.

C.3 PROCESS COMPONENT INVENTORY

C.3.a Intake

The plant intake system was built in 1975. Two round flanged inlets on one intake pipe are located in Millhaven Creek pond, 38 m from shore and submerged 0.9-1.5 m below the water surface. Plate C-1 shows the pond.

Each inlet is 406 mm diameter, and is covered by 38 mm mesh galvanized steel screening. Water entering the inlets flows by gravity to the low lift pump well at the plant via 364 m of 305 mm diameter plastic intake pipe.

When the intake system was built, the inlets had a finer screen of 13 mm mesh and occasional clogging due to frazil ice occurred. Substitution of coarser screens eliminated the problem. A 152 mm diameter pipeline with gate valve is available for backflushing the intake system, using the high pressure distribution main water if necessary.

The intake velocity at the plant flow of 2.05 ML/d is 0.33 m/s. This is well under the MOE maximum Guideline (Ref. 2) of 1.3 m/s based on the Hazen-Williams coefficient recommended value (C value = 100).

Water is conveyed into a low lift pump well, 2.1 m by 3.1 m by 3.1 m SWD with a volume of 20.3 m^3. Since chlorine is added directly to the well, there is constant mixing by a LIGHTNIN Mixer, driven by a 0.37 kW General Electric motor. Plate C-2 shows the mixer in the low lift well. There is no fine screening of raw water before low lift pumping.

C.3.b Low Lift Pumping

There are two low lift pumps located in the low lift pump building shown in Plate C-3. Each pump has the following description:

Type:	Vertical Turbine
Manufacturer:	Crane-Deming
Capacity:	2.05 ML/d
TDH:	9.1 m
Motor:	U.S. Electric Motors
Rotational Speed:	1750 rpm
Power: 3.7 kW	

Each pump is equipped with an automatic pump control valve so that water surge to the reactor clarifier will be eliminated. Only one pump is in operation at a time, while the other pump is used as a standby.

C.3.c Chemical Addition and Flash Mixing

A unit process for flash mixing of raw water and chemicals does not exist. Bentonite clay solution is added to the raw water stream in the 254 mm diameter low lift pump discharge pipe. Alum is added 2 m beyond the point of clay addition and polymer is added an additional 0.5 m beyond the alum.

The flash mixing of all chemicals in the raw water occurs in about 13 m of 254 mm diameter pipe with two 90° bends, resulting in a nominal detention time of 28 seconds.

The energy gradient (G) can be calculated using the following equation (Ref. 3).

$$G = \sqrt{\frac{P}{\mu \upsilon}} \qquad \text{(Eq. C-1)}$$

Where: P = Power input
m = Viscosity of water
υ = Volume of mixing zone

and $P = Q\gamma h_f$

Where: Q = Flow
γ = Specific weight of water
h_f = Head loss through pipe

The above equation was calculated assuming that the mixing zone is the entire volume of pipe between chemical addition and entrance into the reactor. The head loss was calculated from the following equation:

$$h_f = f_1 \frac{L\ v^2}{D\ 2g}$$

Where: f_1 = Friction factor
L = Equivalent length of pipe of mixing zone including mixer and 5-90° bends
D = Pipe diameter
v = Mean velocity in the pipe

The G and Gt values for flash mixing at the Odessa WTP were calculated for the maximum and minimum temperatures of water treated at the plants. These are:

Temperature	G (s^{-1})	Gt (dimensionless)
1°C	55	1540
26°C	78	2028

Typically, G values in the order of 1000 s^{-1} have been found acceptable for flash mixing. The flash mixing at the plant may not be providing sufficient mixing for optimum conditions.

C.3.d Reactor Clarifier

A package unit supplied by EIMCO is used at the Odessa Water Treatment Plant for flocculation and clarification. It is located in a covered concrete brick housing shown in Plate C-4. Water with coagulant and coagulant aids flows into a 2.46 m dia conical flocculation chamber via a 254 mm diameter pipe. The flocculated water exits the chamber and flows upward through the 6.5 m diameter clarification chamber. A schematic of the EIMCO reactor clarifier is presented in Figure C-5. There are three existing sampling points at equally spaced heights in the clarification chamber as well as one that allows sampling of recirculating slurry in the central drum.

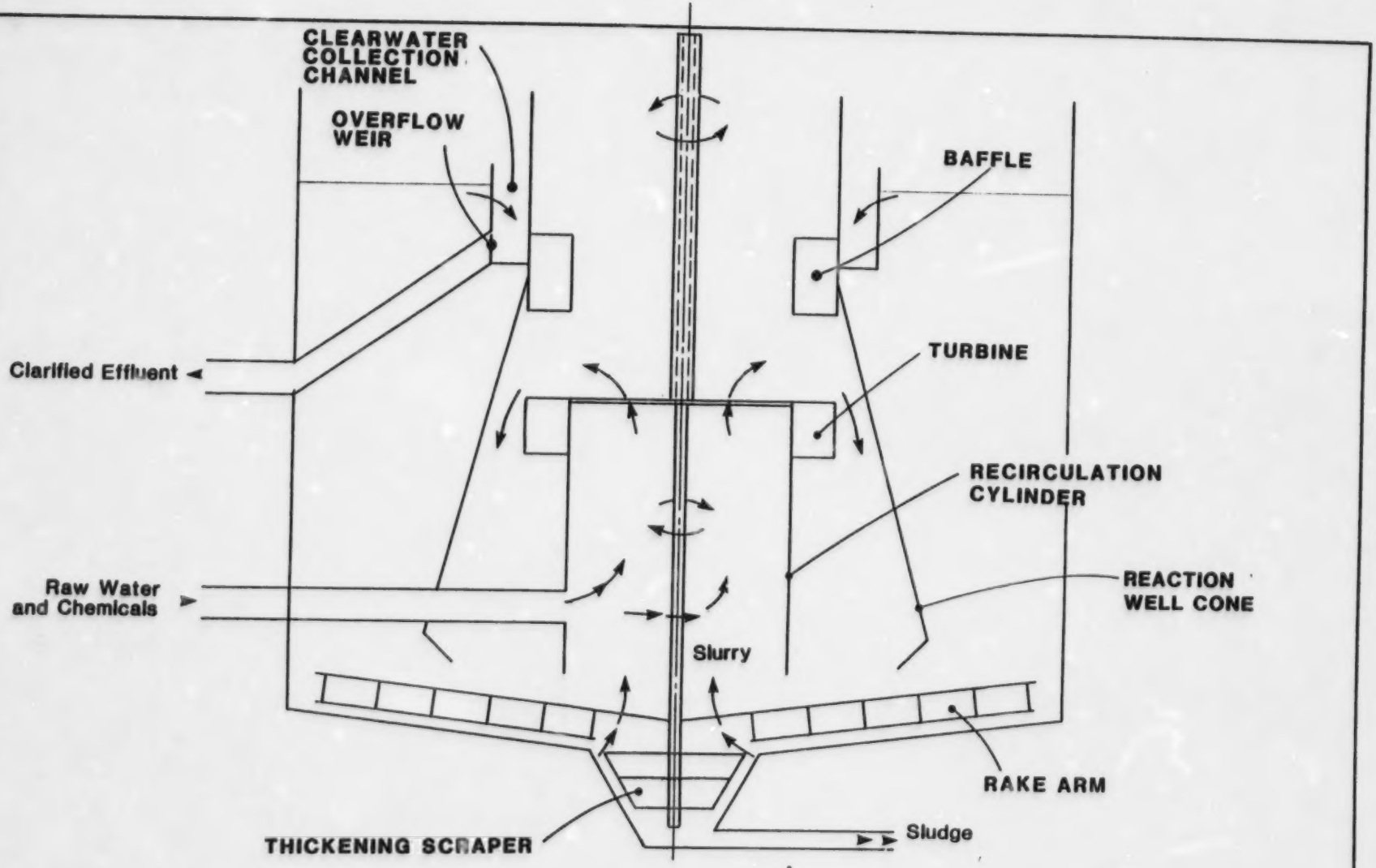


Figure C-5

SCHEMATIC OF REACTOR CLARIFIER AT ODESSA WTP

A 254 mm diameter pipe is available for bypassing the clarifier to the sand filters.

Flocculation

Flocculation and recirculation is accomplished by a reactor-turbine driven by a variable speed drive. The turbine drive is shown in Plate C-5. The turbine drive has the following characteristics:

Manufacturer:	Sterling Motors
Size:	0.37 kW
Rotational Speed:	460-1740 rpm
Turbine Rotational Speed:	5.2-20.8 rpm

According to EIMCO, the manufacturer, turbidity removal is achieved through solids contact in the recirculating chamber and subsequent settling of aggregate floc. The goal of operating this unit is therefore to maintain the largest volume of recirculating sludge that is possible, without having such a high concentration of settled sludge that the sludge blanket can rise and potentially flow through the weir.

The 1.6 m turbine with 12-26.7 cm square blades operates at a rotational speed of approximately 10 rpm, or a tip velocity of 0.84 m/s. The turbine runs constantly, despite the "start-stop" operation of the plant in order to maintain a recirculating sludge concentration in the reactor.

The sediment slurry is drawn from near the tank bottom through a 1.2 m diameter steel recirculation drum. The influent water with additives enters the recirculation drum 1.2 m from the tank bottom. The mixture of slurry and influent is discharged near the surface in the centre of the baffled steel conical reactor compartment. Flow is downward, with large volumes returning to the recirculation drum intake, and the remainder flowing outward under the cone into the clarification compartment.

The energy gradient (G) for paddle turbine drive flocculators can be calculated using the following equation:

$$G = \sqrt{\frac{C_D}{\upsilon}\,\frac{A_p S^3}{V}} \qquad \text{Eq. C-2)}$$

Where:
- C_D = the coefficient of drag (= 1.8)
- υ = the kinematic viscosity
- A_p = the cross sectional area of the paddles normal to the direction of motion
- S = the velocity of the paddles with respect to the liquid
- V = the tank volume

Due to the nature of the design of the reactor at the Odessa WTP, the G value for flocculation cannot be calculated based on the available information. More specifically, neither the volume of the reaction cone that is affected by the turbine nor the relative velocity of the paddles can be accurately determined.

Clarification

The circular concrete clarifier is 6.5 m diameter and has a water depth of 3.2 m with 45 cm freeboard. The water flows upward through the tank, and exits through the overflow weir, 55-3.8 cm diameter submerged orifices spaced equally around the perimeter of the clearwater collection chamber. The 152 mm wide collection channel allows the effluent to flow to the 254 mm diameter ductile iron exit pipe.

The clarifier surface area (excluding reaction chamber) is 28.4 m^2, resulting in a surface overflow rate of 3.0 m/h. This meets the MOE Guideline (Ref. 2) of a maximum of 3.0 m/h for reactor clarifier units.

Sludge Collection

Rake arms rotate within the clarifier in order to draw sludge into the 1.1 m diameter sludge collection cone. A sludge thickening scraper within the cone rotates on the rake arm shaft. The rake arm and scraper drive is shown in Plate C-5. The rake arm and scraper drive has the following description:

Manufacturer:	Brook Electric Motors
Size:	0.56 kW
Rotational Speed:	1800 rpm

The operating rotational speed of the rake arm and scraper is 3 rph, resulting in a rake arm tip speed of 1.0 m/min. The sludge exits the sludge thickening cone to a sanitary sewer on the plant site via a 102 mm diameter PVC pipe with a timed valve opening. The timer can be adjusted to open the valve for 0 to 150 seconds, at a frequency of every 0 to 1 hour. Desludging may also be done manually. Flushing of the desludge pipe with plant supply water takes place before desludging for 0 to 150 seconds. Plate C-6 shows the desludge timer.

Despite the intermittent operation of the plant, the sludge rake and scraper operate continually in order to prevent process upsets.

C.3.e Sand Filters

Water exiting the reactor clarifier flows by gravity through the 254 mm diameter pipe into a 63.6 m^3 capacity steel splitter box, which splits the flow between two sand filters. Plate C-7 shows the splitter box. The filters are package units supplied by Infilco (Division of Westinghouse Canada Ltd.), complete with an analog wall mounted controller.

Each filter unit, made from 6.4 mm steel, is 2.1 m diameter and 4.6 m high, and consists of a 10.2 cm high collection chamber below a 1.4 m high convex roofed filter media inner tank. The remaining 3.1 m height is used for backwash water storage. Figure C-6 presents a schematic of the filter unit. Plate C-8 shows the sand filter units. Plate C-9 shows the wall mounted controller and backwash frequency totalizer.

Filtration

Water enters each filter unit and at the top of the inner media tank via a 152 mm diameter ductile iron pipe, and is distributed evenly over the 3.32 m^2 media surface. Degremont Type D-20 polyethylene nozzles sitting in the 6.4 mm steel floor of the filter compartment allow filtered water to flow into the collection compartment and up around the outside of the media tank to the storage compartment. Plate C-10 shows the inner media tank. A 152 mm diameter exit pipe conveys the filtered water to the intermediate sump.

Each filter is designed for a 57 cm layer of sand (1.9 m^3) and a 4 cm layer (0.14 m^3) of gravel. The sand in the filters was supplied in 1975 and has never been replaced. In August 1988 the media depth was measured to confirm that media has not been lost. The original sand had the following characteristics:

Uniformity coefficient: 1.6
Effective size: 0.55 mm

The 4 cm gravel layer originally consisted of 63 mm x 32 mm particles.

In August 1988, a sand sample was taken from each filter. It was found that the sand was black in colour, possibly due to carbon residue from the discontinued powdered activated carbon process, or organics or manganese in the raw water. In addition, numerous mudballs were found in the media. Plate C-11 shows the media in one tank, showing discolouration and mudballs.

The filtration rate is constant at 12.8 m/h when both filters are operating, and 25.6 m/h when only one is operating. In contrast, the MOE Guidelines (Ref. 2) recommend a maximum rate of 9 m/h for single medium filters.

Backwashing

Backwashing occurs automatically when the pressure head loss through the filter exceeds 1.52 m, as measured by a Mid-west Differential Pressure Gauge (Model 120). A pressure switch, a Flygt Liquid Level Switch (Model ENH-10), then closes a contact to start the backwash procedure. A relay is energized to close the influent valve and open the backwash valve. Valves are 152 mm diameter butterfly type with pressure controlled opening. The timed backwash allows water from the storage tank to flow down, then up via the nozzles through the media, and out to the wastewater sump

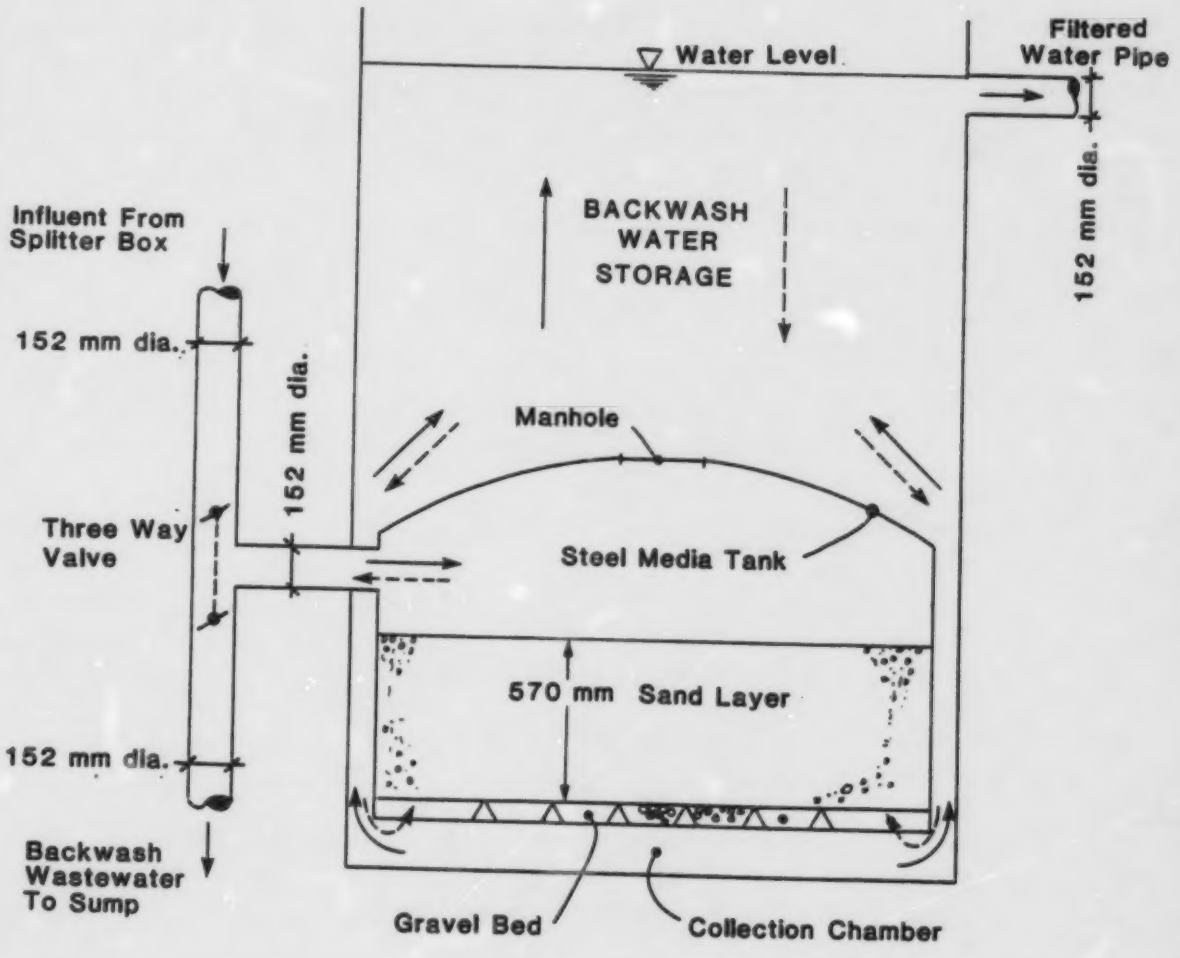


Figure C-6

SCHEMATIC OF SAND FILTER AT ODESSA WTP

through the 152 mm diameter backwash pipe. The pressure controls on the valves cause valve openings and closings to take about 50 s. The timed backwash begins when the valves are completely opened. Filters cannot backwash simultaneously, since one filter will treat the entire flow while the other is backwashing. The timed backwash can be set at a length of 0 to 10 minutes.

As noted, the plant staff calculate the total daily wastewater volume using an assumed backwash water volume of 10 m^3 per backwash. The water volume was measured by CH2M HILL staff during this study in August 1988 for a 4-minute backwash. The results are presented below:

	Filter #1	Filter #2
Total Backwash Cycle Time (includes valve opening/closing)	5.7 min	5.7 min
Volume of Water	4.63 m^3	9.35 m^3
Backwash Flow Rate	55.6 m^3/h	98.4 m^3/h
Backwash Loading Rate	26.1 m^3/m^2h	46.1 m^3/m^2h

The measurement of backwash flow rates in both filters indicated obvious clogging problems in Filter #1, probably associated with mudball formation. These problems cause insufficient backwashing leading to shorter filtration cycles and poorer filtering. Also, because the influent flow to the filters is controlled by gravity, a larger volume of water is being treated by the non-clogged Filter #2, thereby increasing the surface filtration rate and possibly decreasing efficiency in this filter.

Surface or auxiliary wash systems should be provided for gravity filters without air scour to control the formation of mudballs. The Odessa WTP does not have either air scour or surface or auxiliary wash systems in the sand filters.

Plant staff estimate the present backwashing frequency to be about once each 0.1 ML of raw water flow for both filters. That is, for example, that there will be a total of 7 backwashes between the two filters for every 0.7 ML of raw water flow. For a backwash volume of 9.4 m^3, this results in a high wastage of about 9 percent of the raw water flow.

The plant staff have not kept a record of the frequency of backwashes for each filter individually. However, because the clogged filter has an initial higher head loss, it is likely that the filter run length is shorter and backwashing is more frequent for this filter.

Sand Filter Wastewater Sump

Backwash washwater flows into a 3.06 m^3 wastewater sump, with dimensions 0.91 m by 1.83 m by 1.83 m SWD. The sump is equipped with a low and high level probe that control the wastewater pump operation. Wastewater is pumped from the sump to the wastewater equalization tank. The waste sump pump, which was new in 1979, has the following characteristics:

Type: Submersible
Manufacturer: Hydr-O-Matic (Scarboro Pump Mfg. Co. Ltd.)
Capacity: 1.89 ML/d

C.3.f Filtered Water Pumping

Filtered water flows by gravity from the filter units to a filtered water well, built during the expansion in 1979. The well dimensions are 1.83 m by 2.08 m by 3.05 m SWD, with a maximum design volume at high water level of 6.0 m^3.

There are two filtered water pumps, shown in Plates C-12 and C-13. Each has the following specifications:

Type:	Vertical turbine
Manufacturer:	Aurora
Capacity:	2.05 ML/d
THD:	5.8 m
Motor:	U.S. Electric Motors
Size:	2.23 kW

Each pump is equipped with a Singer Model 106 BPC pump control valve, to ensure an adjustable constant head against each pump to allow matching of the flow rate from the equalization well to the low lift section.

Only one pump operates at a time, while the remaining pump is available for standby maintenance and repair.

C.3.g Granular Activated Carbon Contactor

Filtered water is pumped to a granular activated carbon (GAC) contactor for taste and odour control. This unit was added to the plant in 1979. The GAC contactor, a package unit supplied by Infilco, is shown in Plate C-14. A 254 mm dia. pipe allows filtered water to bypass the GAC contactor to the treated water clearwell.

Filtration

The 3.05 m diameter welded 6.4 mm steel gravity contactor contains a 1.2 m GAC media bed. At the design flow of 2.05 ML/d, the surface loading rate is 11.6 m/h.

Typical design loading rates range between 4.6-24 m/h. The empty bed contact time is 6.2 minutes. Figure C-7 presents a schematic of the GAC contactor.

The GAC medium presently in the contactor is Calgon Filtrasorb 400, with the following characteristics:

Effective size:	0.55 - 0.75 mm
U.S. Standard Series size:	>No.12: 5%
	<No.40: 4%

The contactor is a side inlet type with bottom outlet directed through the floor slab and pipe gallery into the clearwell. A vertical trap of 20.3 cm ductile iron pipe on the contactor outlet ensures that the water level in the contactor is maintained above the media bed between pumping periods. A 25.4 mm diameter steel air relief pipe from the top of the contactor is open at all times, except during media removal.

An access manhole is located above the media for inspection and media replacement. Another manhole is located below the media underdrains for inspection and maintenance.

A 254 mm diameter effluent bypass connection permits wasting of treated water to the wastewater sump. This is used after a media replacement to remove any fine carbon particles from the media bed. A long stem operator with a removable wheel extension is available to close the 254 mm diameter butterfly valve, and allow flow to be routed to the clearwell.

Backwashing

A tapping sleeve with a 152 mm diameter gate valve provides distribution system water at pressure from the 254 mm diameter distribution system main. A two-stage pressure reducing and flow control valve set-up using Singer pressure reducing valves with orifice plate reduces the system pressure to a desired value. Plate C-15 shows the valve set-up.

Calgon, the GAC manufacturer recommends an optimum bed expansion of 50 percent or 1.83 m. According to Calgon, the ideal backwash loading rate varies linearly with temperature, from 18.2 m/h for 2°C to 31.7 m/h for 25°C, for Calgon Filtrasorb 400 GAC. The normal backwash pressure used at the plant is 79-89 KPa, resulting in a backwash flow rate of 3.2 to 3.6 ML/d, and a backwash loading rate of 18.2 to 20.5 m/h. There are no seasonal variations in this flow rate. The system is designed to handle up to 148 KPa.

The GAC contactor is backwashed for 10 to 15 minutes resulting in a backwash water volume of 22 to 33 m^3. The recommended backwashing frequency is at least once per week. However, at the Odessa WTP, the GAC contactor is backwashed approximately once in 0.65 ML of flow, resulting in a water usage of approximately 4.2 percent.

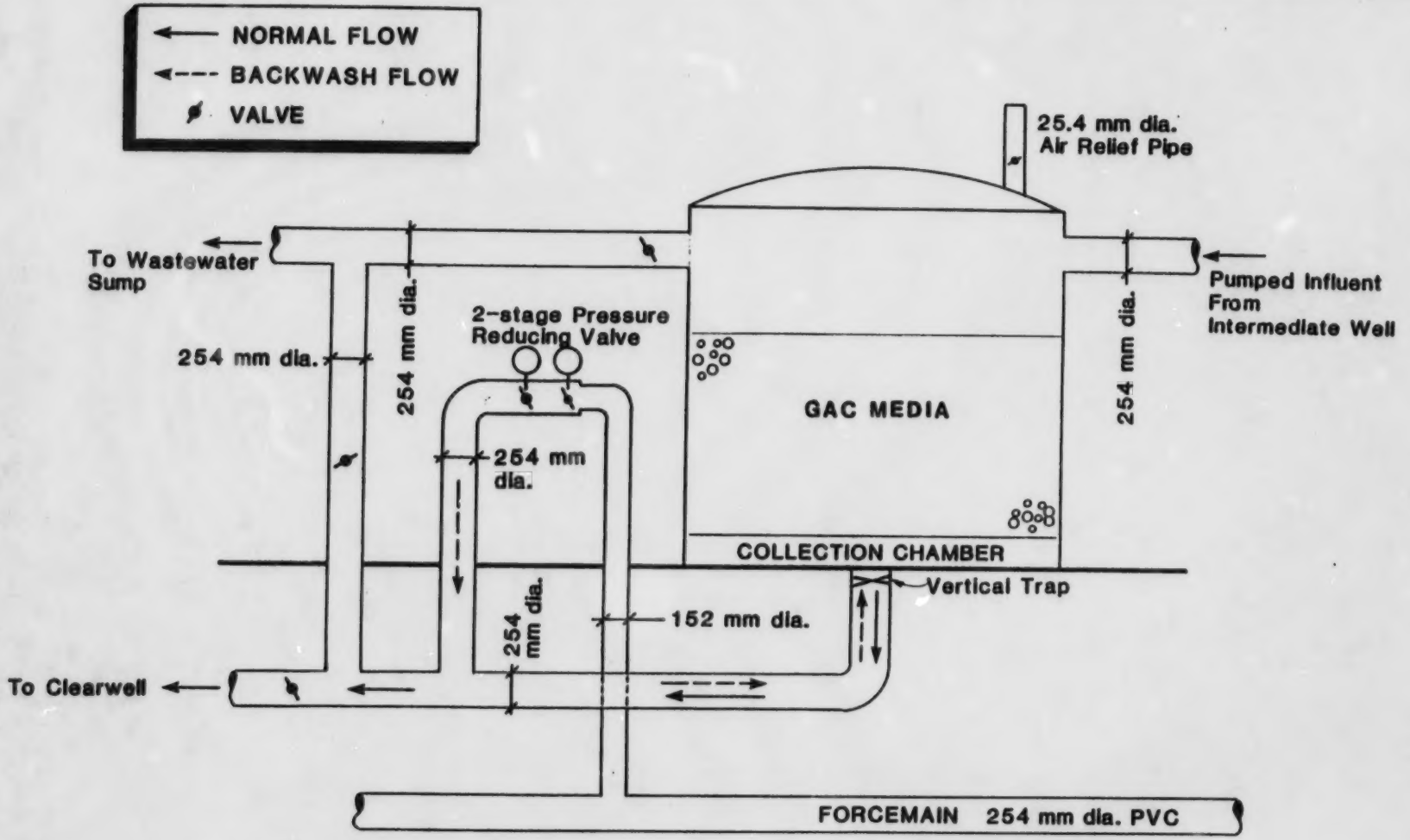


Figure C-7

SCHEMATIC OF THE GRANULAR ACTIVATED CARBON CONTACTOR AT ODESSA WTP

Since backwashing is a manual operation, the low lift system and intermediate pumps are locked out before starting. The filter outlet valve to the clearwell and both butterfly valves on the intermediate pump discharge are closed. The backwash valve on the contactor is then opened using the chain operator and the backwash cycle is started. A detailed description of the backwashing procedure is presented in Section D.4.g.

C.3.h Wastewater Equalization Tank

Backwash and drainage from the GAC contactor and pumped wastewater from the sand filter sump is conveyed to a concrete wastewater equalization tank, a part of the 1979 expansion. The tank holds a high water volume of 25.6 m^3 and has dimensions of 3.4 m by 2.6 m by 3.05 m SWD. The purpose of the tank is to provide equalization storage for backwash water, so as not to overload the sewer.

Two pumps are located in 46 cm square sumps at the bottom of the well, and have the following description:

Manufacturer:	Hydr-O-Matic, Scarboro Pump Mfg. Co. Ltd.
Type:	Submersible
Capacity:	4.91 ML/d

Pump discharge is to a 102 mm diameter cast iron pipe through a trap seal in the 204 mm diameter sanitary sewer pipe. A flexible connection on each pump allows removal for servicing.

C.3.i Clearwell

Treated water from the GAC contactor flows by gravity into a clearwell, with dimensions 3.05 m by 3.05 m by 3.20 m SWD. At the high water level, the total volume stored is 28.4 m^3, resulting in a minimum hydraulic retention time during high lift pump operation of 20 minutes. There are two high lift pumps (Plate C-16), each with the following description:

Type:	Vertical turbine
Manufacturer:	Crane Demming Fig. 4700
Capacity:	2.05 ML/d
TDH:	51.8 m
Motor:	U.S. Electric Motors
Size:	18.6 kW
Rotational Speed:	1770 rpm

In 1979, the high lift pumps were supplied with Singer Model 106 BPC-R surge control valves.

Water is pumped into 15.2 cm diameter outlet connected to the 25.4 cm diameter PVC distribution main, which leads to the storage tower and distribution system.

C.4 CHEMICAL SYSTEMS

C.4.a Settling Aid

Powdered bentonite clay, brand named CA25 CLAY, is supplied in 23 kg bags by Calgon, in Bramalea, Ontario. The packaged clay is stored in a dry storage area on the main floor of the low lift pump building. A 5 percent solution is made up manually each day in a 2.1 m^3 polyethylene drum. A LIGHTNIN Mixer with a 0.25 kW drive operates continually in order to keep the clay in a homogenous solution. The day tank is located in the low lift pump building, and is shown in Plate C-17.

Bentonite clay solution is pumped from the day tank through about 10 m of 25 mm diameter rubber hose, to the application point in the 254 mm diameter low lift discharge pipes just after the low lift pumps.

The clay solution feed pump has the following description:

Type:	Single head, 3 pulley drive system
Manufacturer:	Wallace and Tiernan

The approximate pump capacity range is 0-500 mL/min.

C.4.b Coagulant

Liquid alum ($Al_2(SO_4)_3 \cdot 14H_2O$) is supplied to the Odessa Water Treatment Plant by Alcan Aluminum Ltd. of Montreal, Quebec.

A main liquid alum storage tank sits on a platform outside the low lift building. The heat treated fibre reinforced plastic tank is a vertical standing cylinder, 3.05 m diameter and 3.67 m high, with a storage capacity of 26.8 m^3. Plate C-18 shows the alum storage tank.

Alum flows by gravity through about 3 m of 16 mm diameter polyethylene tubing to the 2.05 m^3 polyethylene day tank in the low lift building. Plate C-19 shows the alum day tank, and feed pump.

Alum is applied to the raw water flow at a point in the 254 mm diameter low lift discharge pipe 3 m after the clay addition point. The alum feed line is 14 m of 5 mm diameter polyethylene tubing.

The alum feed pump has the following description:

Type:	Single head, 3 pully drive
Manufacturer:	Wallace and Tiernan

The approximate pump capacity range is 0-250 mL/min.

C.4.c Coagulant Aid

An anionic polyacrylamide commercial polyelectrolyte (Aquafloc 6465) is used as a coagulant aid. The polymer, supplied by Dearborn Chemical in Mississauga, is delivered to the plant in powdered form.

A 2.05 m^3 polyethylene drum serves as the polymer mixing and storage tank. Approximately every 2 weeks, powdered polymer is mixed with the plant supply water to form a polymer solution. The drum is equipped with a LIGHTNIN Mixer with a 0.25 kW drive. Plate C-20 shows the polymer day tank mixer, and feed pump. When the polymer solution is made up, it is mixed at high speed for 5-10 minutes then slowly for 1 hour. During this period, the low lift pumps are locked out.

The polymer feed pump has the following description:

Type:	Single head, 3 pully drive system
Manufacturer:	Wallace and Tiernan

The approximate pump capacity range is 0-250 mL/min.

The polymer solution pumps operate only during low lift pump operation.

C.4.d Disinfection

Chlorine gas is supplied to the plant in 68 kg cylinders, by Stan-Chem (Division of CIL) in Toronto, Ontario. The chlorine cylinders are kept in the chlorine room in the high lift building. At any time there are 10 empty and full cylinders at the plant.

The two cylinders in use feed one of two ADVANCE chlorinators. Feed volume is provided by adjustable rotameter flow meters. The feed capacities of the chlorinators are 11.4 kg/d and 22.8 kg/d, respectively. The chlorinator not in use is available for standby. Water to the chlorinators is supplied by the plant service.

Pre-chlorine application is directly into the low lift wet well where the raw water is constantly mixed for even distribution. Chlorine is applied via 15 m of 9.5 mm dia polyethylene tubing.

There are two post-chlorination application points. When the GAC contactor is operating chlorine is applied to the 254 mm diameter GAC effluent pipe, prior to entering the clearwell. If the GAC contactor is bypassed, chlorine is applied directly into the clearwell.

The chlorinator feeds chlorine solution to raw and treated water only during low lift pump operation.

C.5 SAMPLING

Sample lines for MOE DWSP sampling of raw water and final treated effluent were installed at the Odessa WTP in 1988. Both sample lines are made from stainless steel and supply stainless steel taps, at a concrete trough above the wastewater equalization tank in the high lift pump building. Plate C-21 shows the sample taps.

Raw water is pumped through 41 m of 25 mm diameter stainless steel pipe to the sampling tap. The sample is taken from the 305 mm diameter raw water intake pipe prior to the entrance to the low lift well. The pump design details were unavailable.

Treated water is sampled from the distribution system main. The water travels 12 m through 19 mm diameter stainless steel pipe to the sampling tap.

Table C-1 presents the sampling line details.

Table C-1
DETAILS OF IN-PLANT SAMPLING LINES

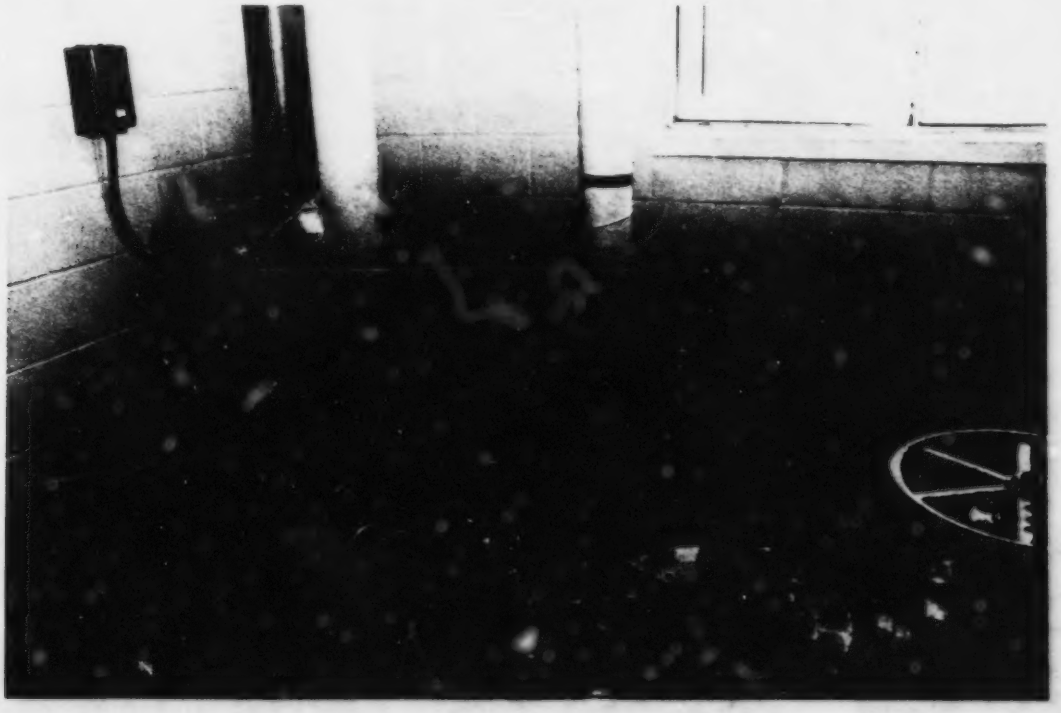
Location	Length (m)	Diameter (mm)	Flow* (L/min)	Velocity* (m/s)	Travel Time* (sec)
Raw Water (intake pipe)	41	25	42	14.3	3
Final Treated Water (distribution system main)	12	19	113	3.84	0.3

*Based on volume/stopwatch measurements at the plant in August 1988.

C.6 PLATES

Plate C-1, MILLHAVEN CREEK POND ▲

▼ Plate C-2, LIGHNIN MIXER IN LOW-LIFT WELL



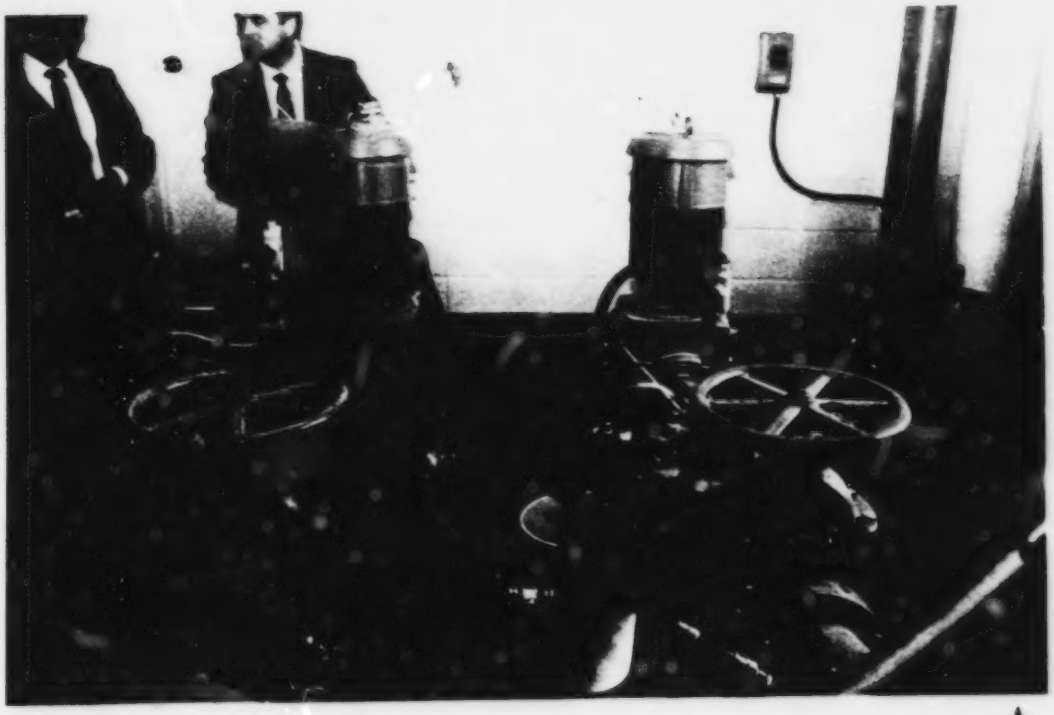
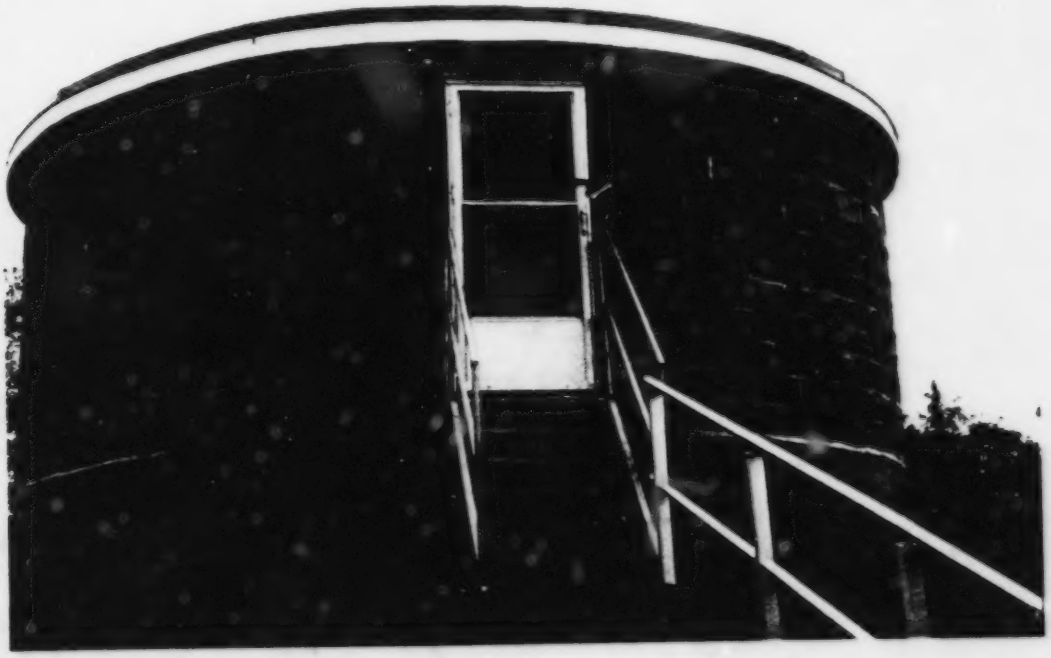


Plate C-3, LOW-LIFT PUMPS ▲

▼ Plate C-4, REACTOR CLARIFIER BUILDING



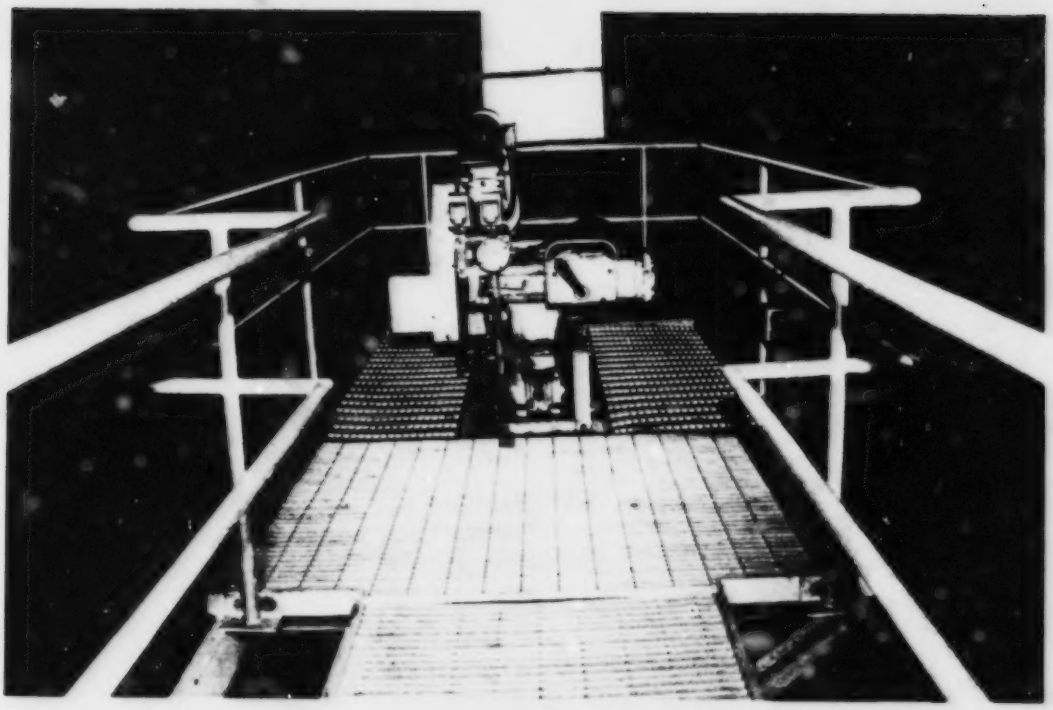
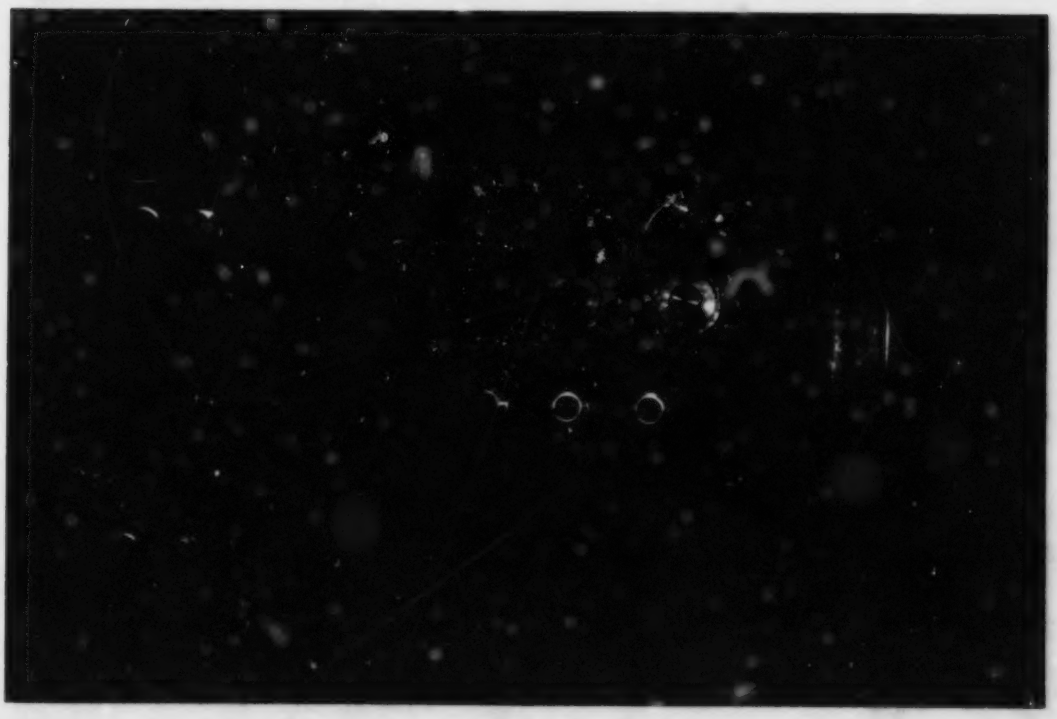
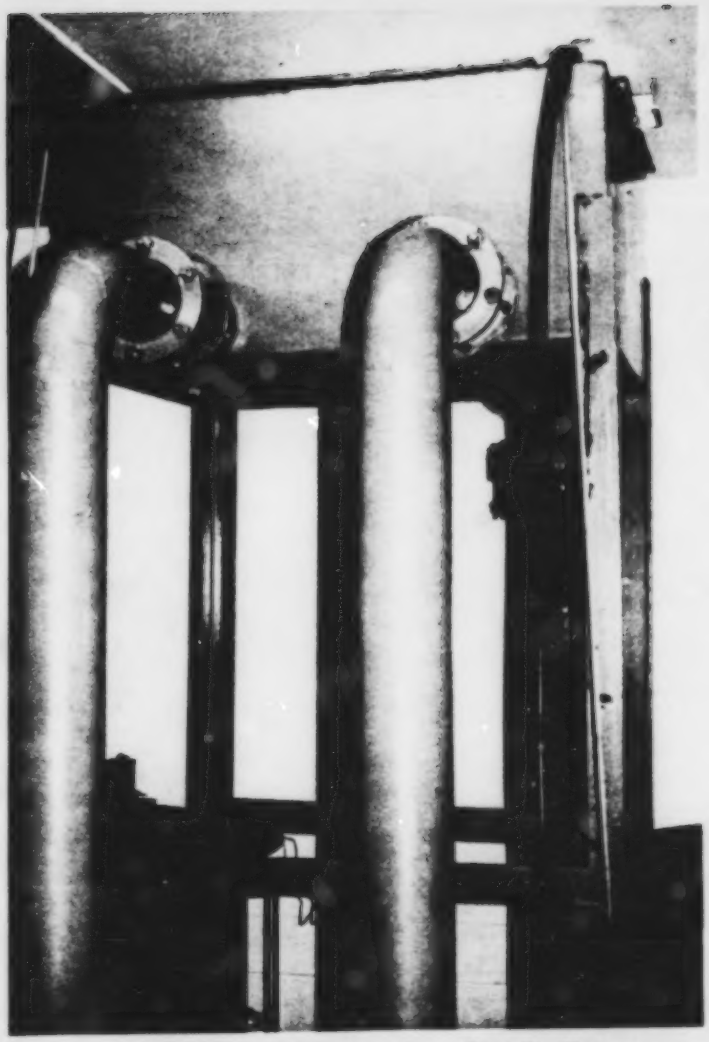


Plate C-5, FLOCCULATOR TURBINE DRIVE ▲

▼ Plate C-6, DESLUDGE TIMER





◀ Plate C-7,
SAND FILTER
SPLITTER BOX

Plate C-8,
SAND FILTERS ▼

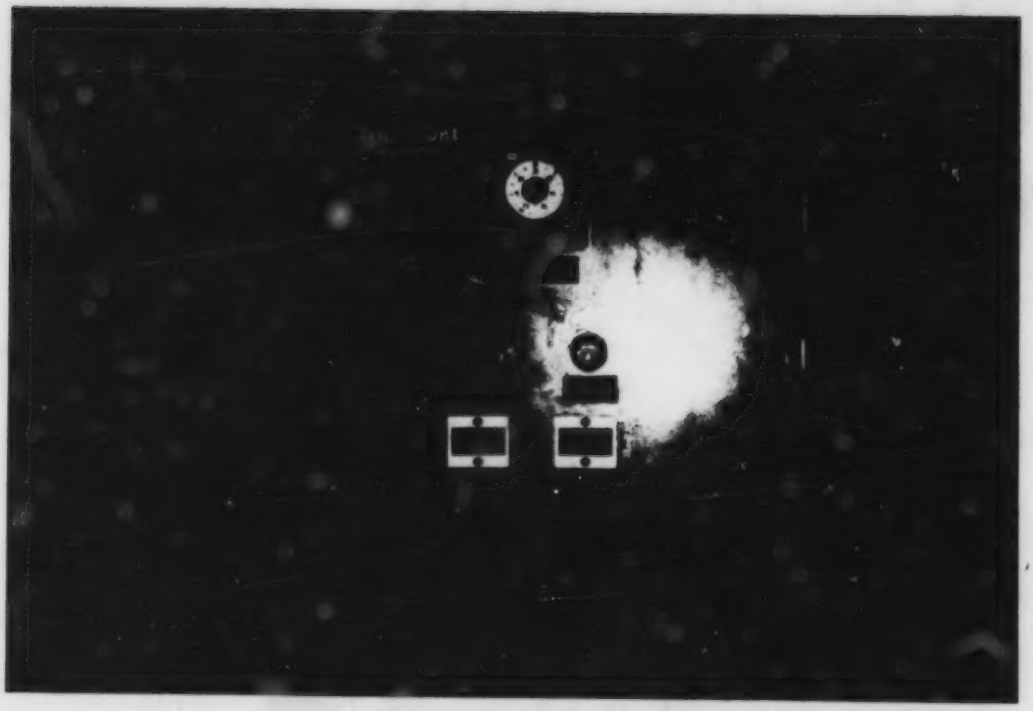
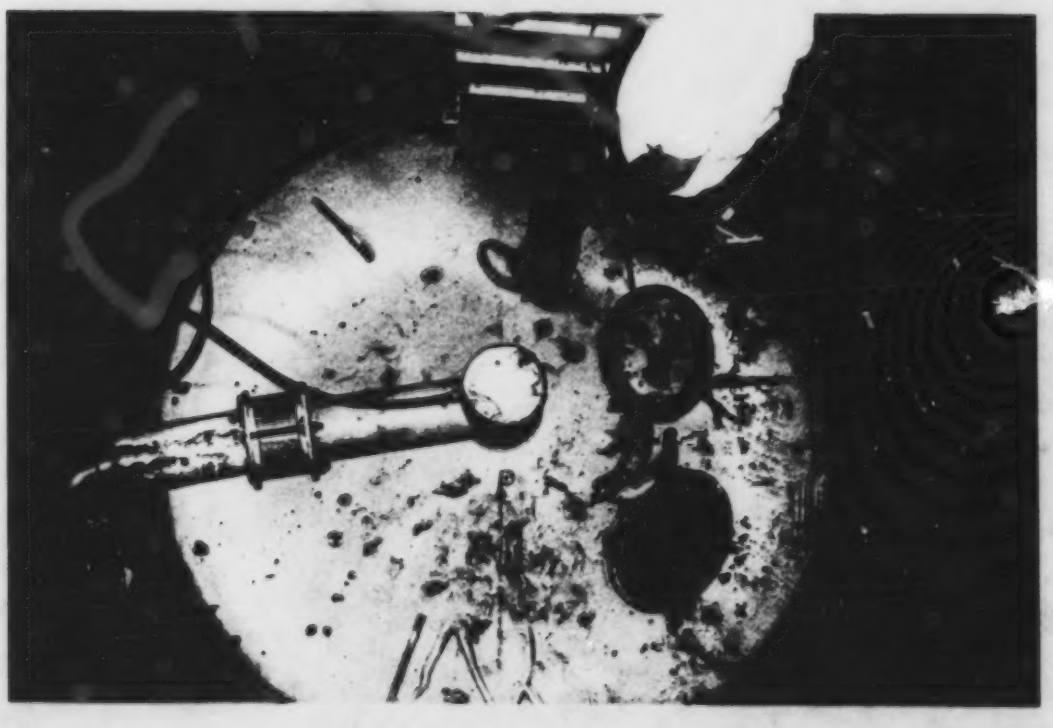
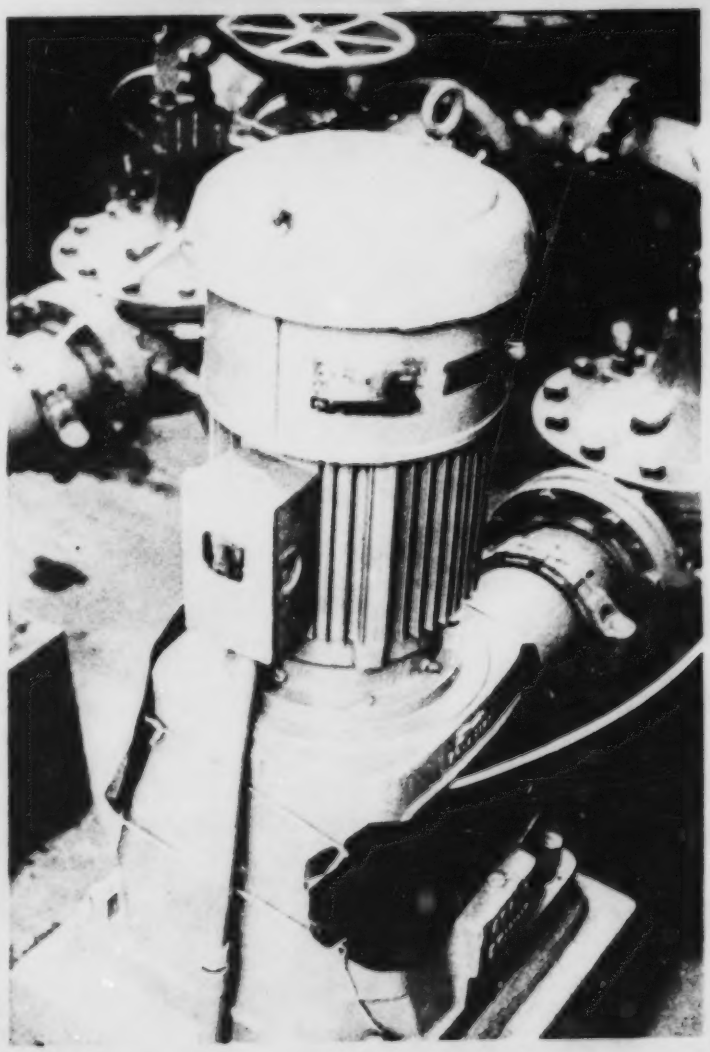


Plate C-9, SAND FILTER BACKWASH CONTROLLER

Plate C-10, TOP VIEW OF INNER MEDIA TANK





▲ Plate C-11,
MEDIA IN
FILTER No. 1

◀ Plate C-12,
INTERMEDIATE PUMP

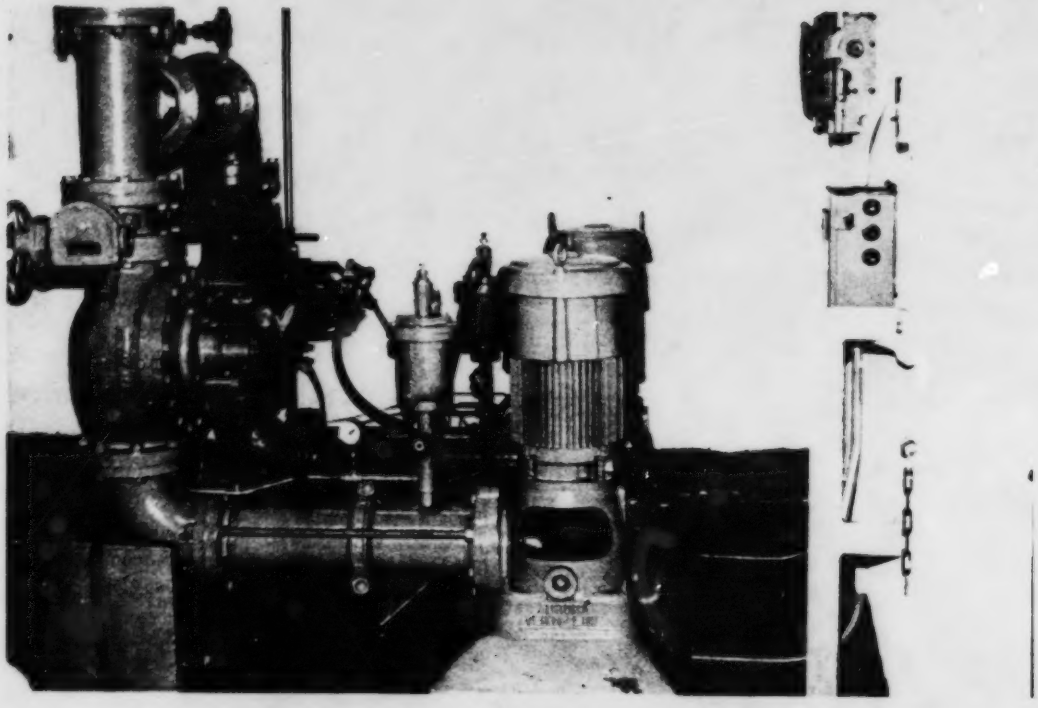


Plate C-13,
INTERMEDIATE PUMPS

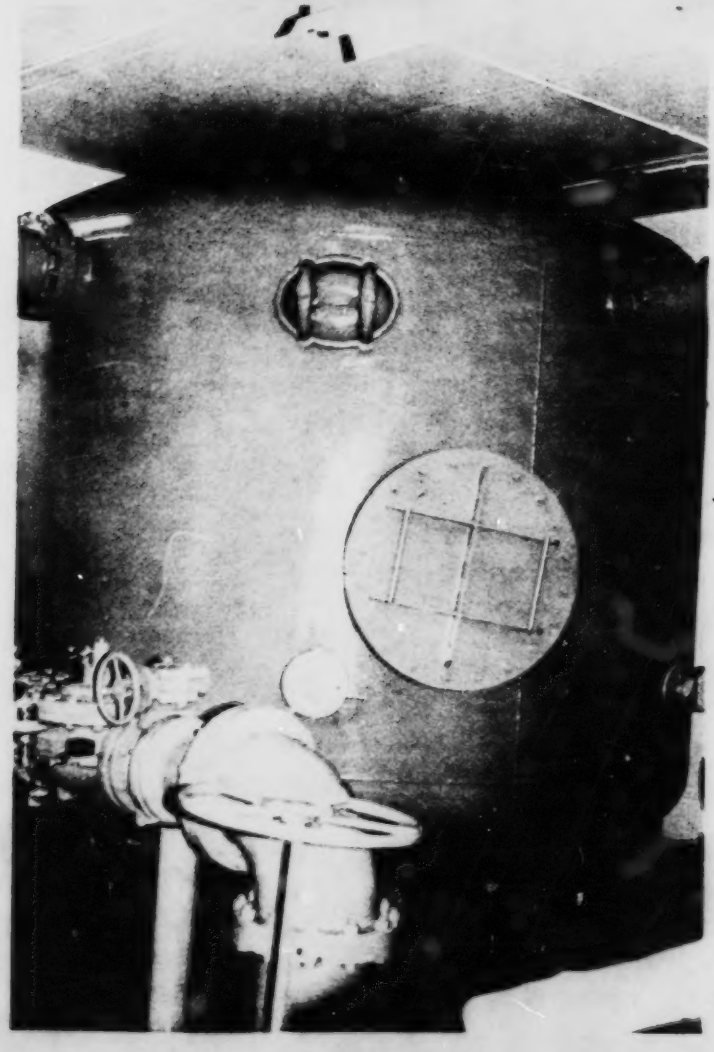


Plate C-14,
GAC FILTER

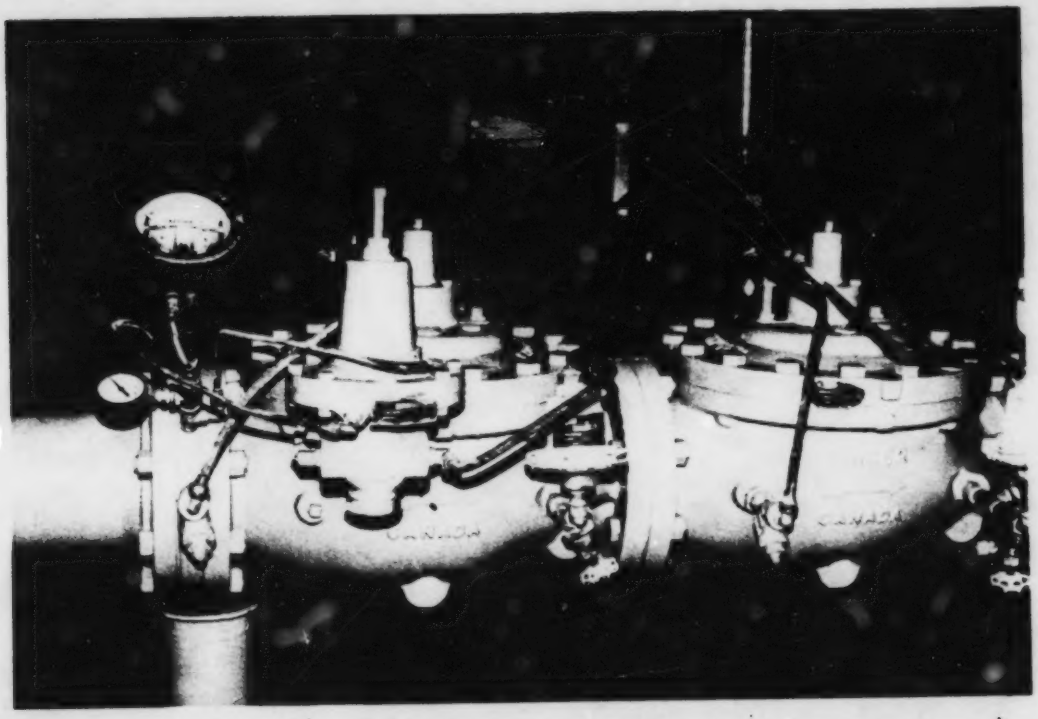
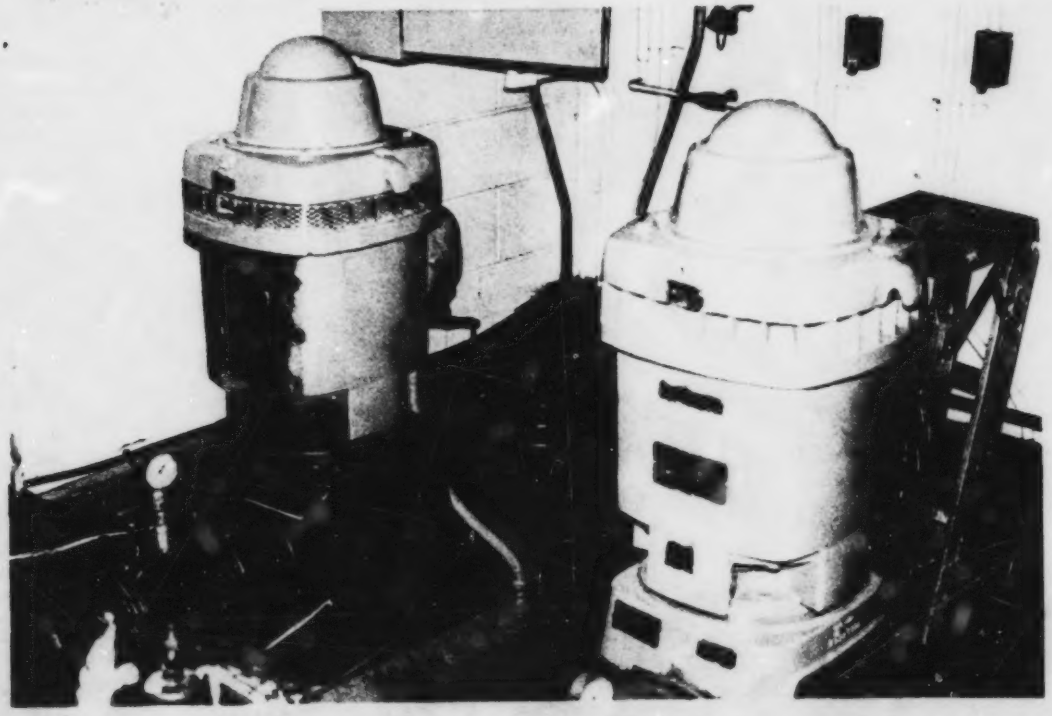


Plate C-15, PRESSURE REDUCING VALVE SET-UP ▲

▼ Plate C-16, HIGH-LIFT PUMPS



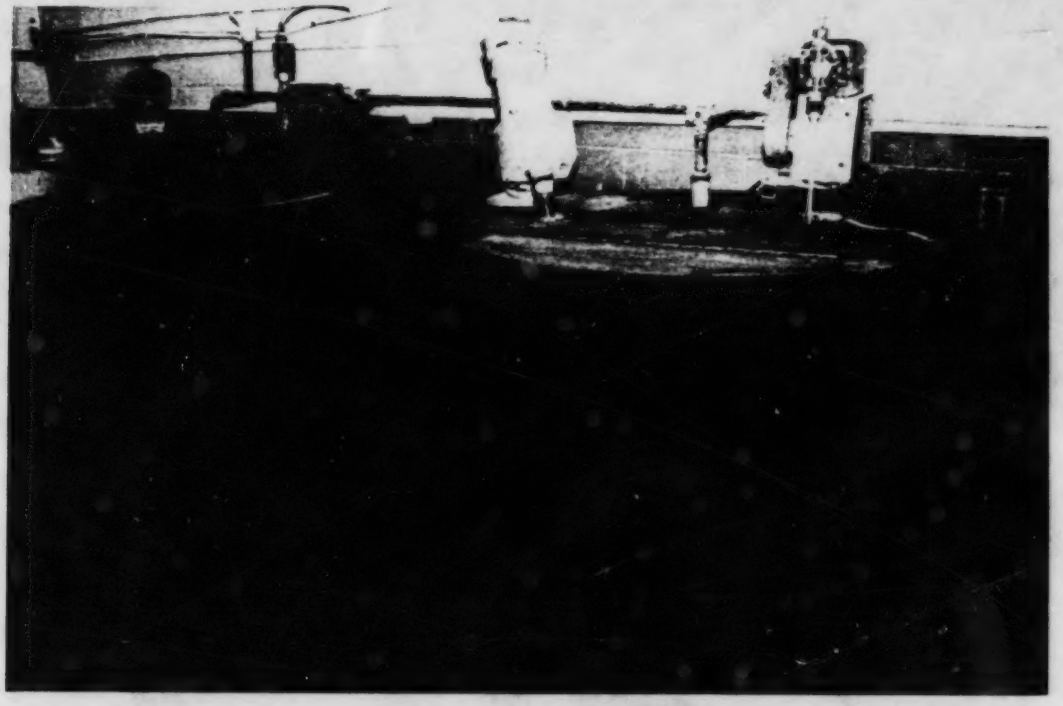


Plate C-17,
BENTONITE CLAY
DAY TANK

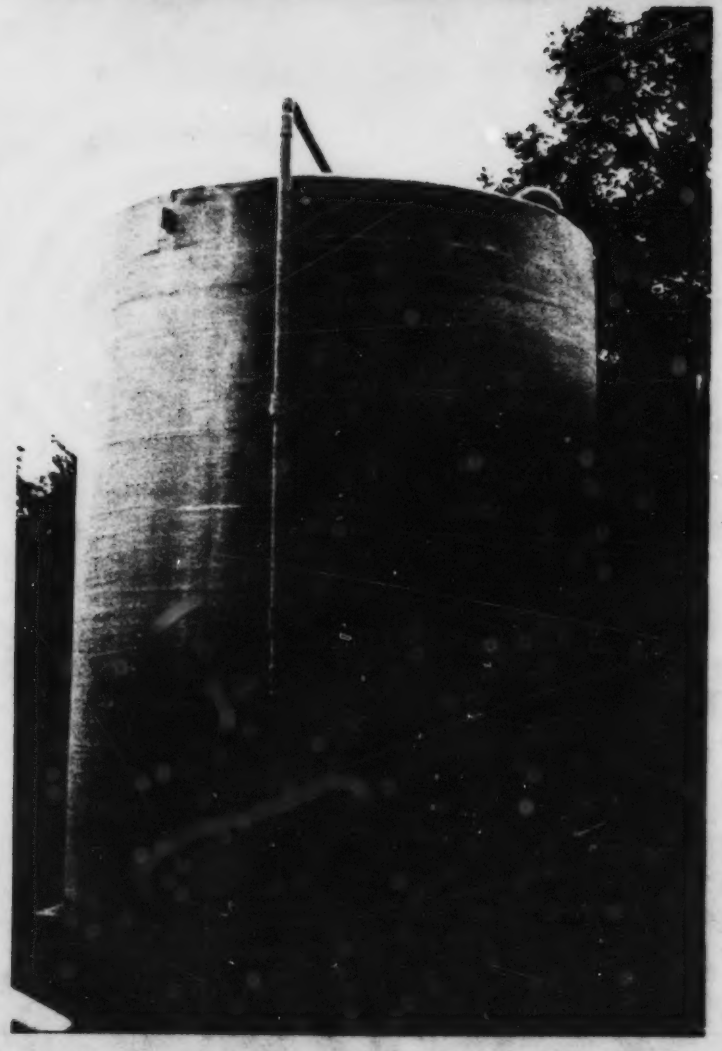
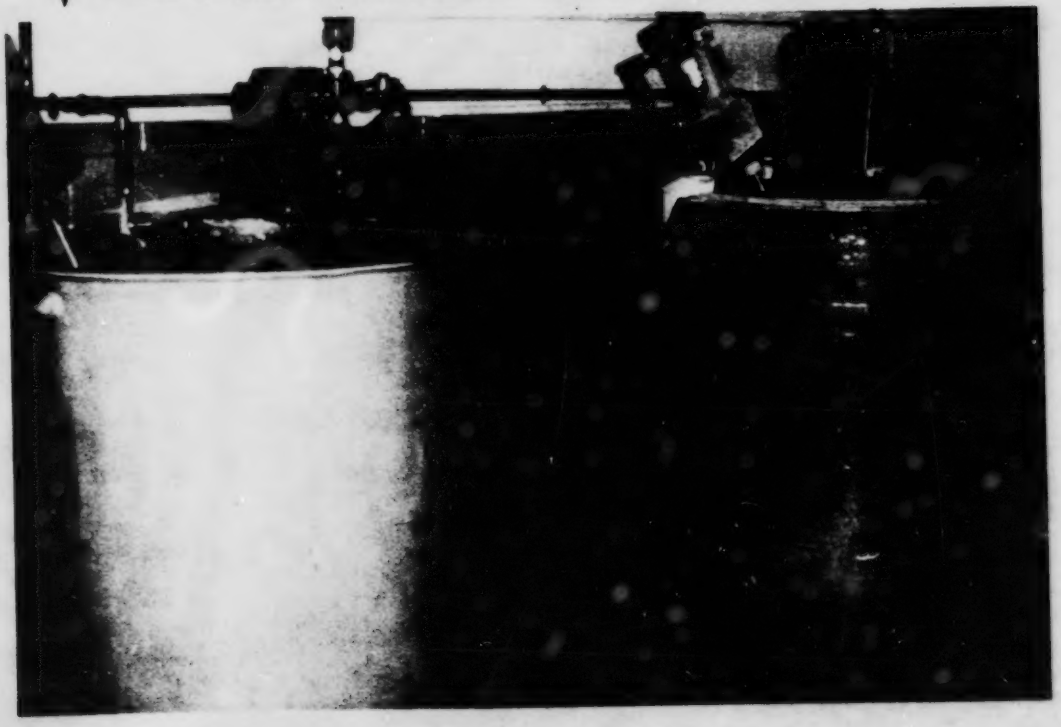


Plate C-18,
MAIN ALUM
STORAGE TANK

Plate C-19, ALUM DAY TANK & FEED PUMP ▲

▼ Plate C-20, POLYMER DAY TANK, MIXER & FEED PUMP



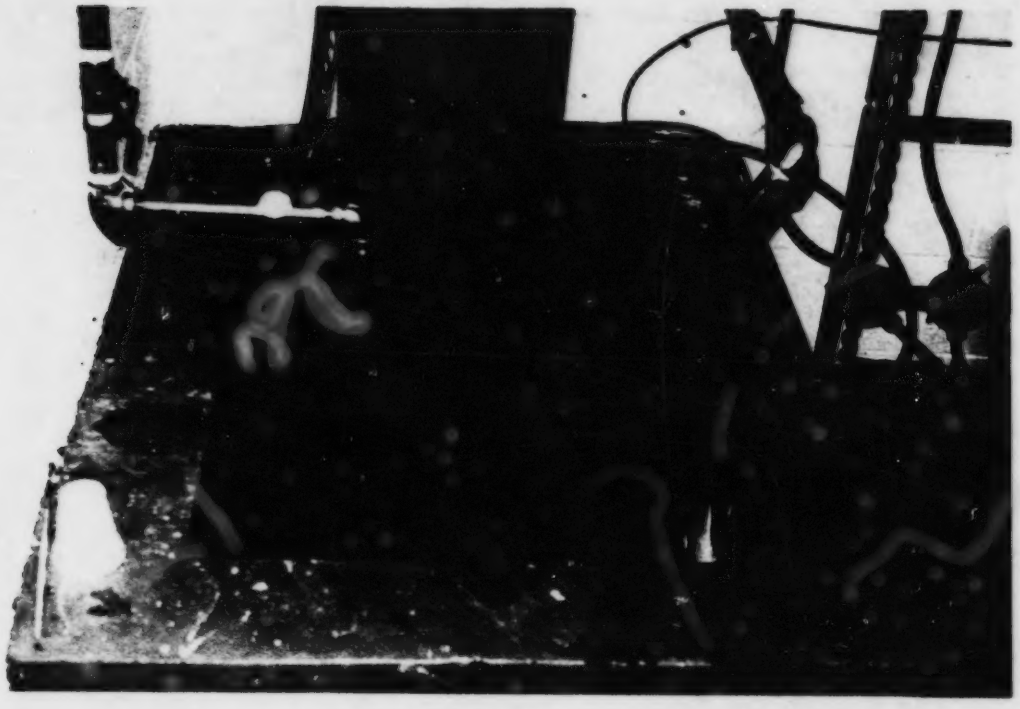


Plate C-21, DWSP SAMPLE TAPS

D. PLANT OPERATION

D.1 GENERAL DESCRIPTION

The Odessa Water Treatment Plant treats raw water from Millhaven Creek through processes that include: flocculation, clarification, rapid filtration, and granular activated carbon (GAC) treatment. Alum is added to the raw water as a coagulant, and a commercial polymer, as a coagulant aid. Bentonite clay is added to aid flocculant settling. Chlorine is added to both raw and treated water for disinfection.

At present, the Odessa WTP is not classified in the MOE Classification Program. The plant is operated by the MOE, and the plant staff includes one Chief Operator and one Operator. For 9 months each year another person is hired to help with regular operational duties, and in the remaining 3 months, a summer student fills this position. Each of the staff members work 8 hour days, Monday to Friday. All of the Water Treatment Plant personnel are also responsible for the Odessa Water Pollution Control Plant (WPCP), located 2 km from the WTP site, as well as the Amherstview sanitary sewage lagoon and pumping station. As a result, the plant is often not manned during daytime hours. Contingency alarms are in place at a number of locations in the plant to indicate process upsets and general emergencies such as chlorine gas leaks and fires. A list of alarm locations is presented below:

- Storage tower high level, low level
- Clearwell high level, low level
- Waste sump high level
- Filter room flood
- Intermediate pipe gallery flood
- Intermediate well high level
- Chlorine leak
- Raw water wet well low level
- Low chlorine residual (not in use)

When an alarm is activated, the low lift pumps are automatically locked out until the alarm situation is resolved and the system is manually switched back to automatic. There are no online performance monitoring systems that will alarm if plant performance deteriorates. More specifically, the treated water residual chlorine alarm is not in use.

The Chief Operator and Operator alternate bi-weekly the responsibility of being "on-call" for alarm situations during non-working hours.

The plant operates automatically in a "start-stop" manner. Low lift and intermediate pumps transmit water through the treatment system at the plant rated capacity of 2.05 ML/d. Water is conveyed to the distribution system storage tower by high lift pumps. The frequency of pump starts is not recorded at the plant. Operation is monitored by daily flow volumes.

D.2 FLOW CONTROL

Low and high level probes in the clearwell transmit a signal controlling low lift pump operation. Only one low lift pump operates at a time, pumping at a rate of 2.05 ML/d, while the other pump is available for standby. The automatic system is manually overridden only to stop low lift pump operation for maintenance and repair. Low lift pumps provide sufficient head for water to flow through the flocculation/clarification and filtration processes.

Two filtered water pumps are available to pump water from the filtered water well to the GAC contactor. One filtered water pump is the main operating pump, while the other is available for standby. Pumping is controlled automatically, depending on signals transmitted from high and low water level probes in the filtered water well. The pumping rate during operation is constant, and equivalent to the plant capacity of 2.05 ML/d. As above, the automatic system is manually overridden only to stop filtered water pump operation for maintenance and repair.

One of two high lift pumps at the plant pumps water to the Town distribution system and storage tower. The second pump is available for standby. The high lift pump operation is automatic, depending on the high and low water level probes in the storage tower. High lift pumping during operation is at the constant rate of 2.05 ML/d.

Manual control of high lift pumps is only used to shut the pumps off for maintenance and repairs and during low lift pump shut downs, so that the clearwell does not drain down to the low level alarm.

D.3 OPERATION OF SPECIFIC COMPONENTS

D.3.a Intake

The intake system consists of 2 coarse screened flanged inlets that draw water into a 305 mm pipe which conveys water by gravity to a low lift wet well. A gate valve in the intake pipe allows flow to be stopped for maintenance and inspection. A 152 mm backflush line with gate valve is available for cleaning the intake pipe.

Frazil ice problems have not occurred since a coarse intake screen was installed. Once or twice each summer, the intake system is inspected and cleaned. Plant staff walk out to the inlets in the shallow Millhaven Creek and visually inspect and clean all algae growth. The intake pipe is backflushed for about 15 minutes. The wet well is emptied and washed down. It has not been necessary to remove sediment from the well.

D.3.b Low Lift Pumps

Each low lift pump is equipped with an automatically operated pump control valve in the 152 mm discharge line in order to eliminate a surge of water to the reactor clarifier. A manually operated gate valve in the discharge line is opened for the main operating pump.

The main operating pump is rotated every 3 to 4 weeks when the screens on the pump intake are removed and cleaned.

D.3.c Flash Mixing

There is no flash mixing process installed at the plant. Flash mixing occurs for a nominal time of 11 seconds in the pipe to reactor clarifier. A previously noted, this results in energy gradients (G) in the range of 41-54 s^{-1}. This range is significantly lower than acceptable G ranges for flash mixing.

D.3.d Flocculation and Clarification

The raw water with coagulant, coagulant aid and settling aid enters the reactor clarifier for flocculation and sedimentation.

The flocculation process involves slow mixing of influent and recirculated sludge by a variable speed turbine. The only control method available for the flocculation process is the control of turbine speed, presently operating at about 50 percent of capacity, or 10 rpm. The turbine speed has not been readjusted in plant history.

Slurry from the flocculation chamber continually enters the clarification chamber during low lift pump operation. Two sludge scraper arms revolve on the tank bottom to convey sludge into a thickening cone. Normally, desludging from the clarifier is a manual operation. The frequency and interval of desludge is based on the plant Operator's observation of the sludge blanket level. The Operators attempt to keep the sludge blanket level low in the clarifier, but not so low that they will lose it through desludging, because of the difficulty in re-establishing a blanket. Desludging takes place as often as a few times a day to as infrequently as once in 3 days. Typically, the sludge blanket level is lowered each weekday evening so that it can rise during the night or weekend, to allow wasting the morning of the next work day.

There is equipment at the plant for automatic desludging for a set interval and frequency to allow wasting of sludge at a set volume per volume of water processed. However, the plant operators have found it difficult to keep the sludge blanket stable using the automatic system, because of the intermittent operation of the plant. More specifically, the degree of the sludge thickening varies with the length of the period of plant operation and it is therefore difficult to find one desludge setting that will waste the appropriate volume of sludge for the varying degrees of thickening. Sludge settling tests are not performed at the plant.

The turbine and sludge scraper system operate continuously despite the start-stop operation of the plant, so that continual sludge thickening occurs even when the low lift pumps are not operating.

The reactor clarifier housing was not insulated and therefore, the surface of the clarifier froze during the winter. Usually, normal operation continued because a heat tracer prevented the weir from freezing. Occasionally, a large ice mass developed in the clarifier compartment, causing a reduction in nominal retention time and a reduction in performance efficiency. When the ice mass got large enough for a noticeable deterioration in clarified water quality, it was manually broken up and removed. In March 1989, the roof of the structure was insulated in order to prevent these problems from occurring in the future.

A clarifier bypass can convey the raw water directly to the sand filters. In the past, during periods of clarifier sludge blanket upsets or during repair work, the clarifier has been bypassed. Periods of bypassing have ranged in length from one day to several months.

The reactor clarifier is drained and cleaned once each year in the spring.

D.3.e Sand Filters

The two sand filters at the plant treat clarified water at a constant rate of 2.05 ML/d (total) during low lift pump operation. When one filter is backwashing, the other filter will treat all of the plant flow. There are no procedures practised for process control, for example turbidity measurements.

The automatic gravity fed backwashing process uses the filtered water in the storage tank above the filter. The backwashing process is described below:

1. The pressure head probe measures a 1.52 m head loss across the filter media bed.

2. The filter influent valve closes and the backwash effluent valve opens. The filtered effluent valve closes.

3. Backwashing occurs for 4 minutes. The storage water flows downward through the storage container, upward through the media tank and exits via the backwash effluent pipe to the sand filter wastewater sump.

4. The backwash effluent valve closes simultaneously with the opening of the filter influent valve and the filtered effluent valve.

5. Normal filtering resumes.

The filters are not equipped with air scour or surface auxiliary wash systems.

There are presently no filter maintenance or inspection routines utilized at the plant. The media has been inspected only once; during this study in August 1988. The media depth confirmed the fact that media has not been lost. However, the sand was coated

with a thin layer of black powder, possibly as a result of the old PAC process, raw water organics or inorganics (e.g. manganese). In addition, a significant quantity of mudballs were interspersed with the media.

The volume of water used during backwashing was also measured in August 1988. It was found that one of the filters was accepting water at about half of the rate expected, as noted by the performance of the other filter, indicating that the equipment or media or both required maintenance.

D.3.f Filtered Water Pumping

A 254 mm gate valve on the sand filter effluent pipe is opened to allow flow into the filtered water wet well. Water is drawn from the filtered water well by one of the two intermediate pumps. Each pump discharge line is equipped with pump control valves for control of pumping head.

The main operating pump is rotated each month. At this time the screen on the pump inlet pipe is cleaned. The filtered water well is not routinely emptied and cleaned.

D.3.g Granular Activated Carbon Contactor

Filtered water from the filtered water well is pumped through a GAC contactor for taste and odour control. The GAC contactor treats water at a constant rate of 2.05 ML/d during pump operation. There are no specific process parameters used to control the operation of the GAC filters.

It is recommended by the designer that GAC contactor media cleaning by backwashing be done at least once per week. However, as described in Section C.3.g, more frequent washing is required, as indicated by:

- The 25 mm dia. air relief pipe on the roof of the filter begins to "bleed"
- The pressure gauge on the filtered water pump discharge pipe measures a pressure of greater than 34.5 kPa

The plant staff presently backwashes as often as once per day in the summer months. Backwash water is high in colour and turbidity, indicating that turbidity removal is taking place in the GAC contactor. Turbidity measurements are not done in GAC contactor influents, so turbidity removal efficiency cannot be determined. The backwashing procedure is a manual operation which uses water from the treated water distribution system main. The sequence of events in the backwash cycle are as follows:

1. Low lift pump operation is locked out.
2. Filtered water pump operation is locked out.

3. Filtered water pump discharge valves are closed.

4. GAC contactor effluent to clearwell valve is closed.

5. GAC contactor backwash outlet valve is opened.

6. Backwash water control valve is slowly opened to reach a water pressure of 103.4 kPa.

7. Backwash continues for about 15 minutes. The 103.4 kPa pressure is maintained.

8. The backwash water control valve is closed.

9. The GAC contactor backwash outlet valve is closed.

10. The GAC contactor effluent to clearwell valve is opened.

11. The low lift pumps are switched to automatic control.

12. The intermediate pumps are switched to automatic control.

The GAC media is inspected every few months to ensure that fouling is not occurring and was last replaced in March 1988.

D.3.h Clearwell

GAC contactor effluent receives post-chlorine addition before entering the treated water clearwell. When the GAC contactor is bypassed, post-chlorine addition is directly into the clearwell. The clearwell provides a minimum chlorine contact time for treated water of 20 minutes, before water is drawn by a high lift pump into the forcemain.

The treated water clearwell is inspected once or twice a year from an access manhole. The concrete well has been drained and cleaned twice since 1974.

D.4 CHEMICALS USED IN PARTICULATE REMOVAL

Bentonite clay solution, liquid alum and polymer (Aquafloc) solution are added in that order to the low lift discharge pipe leading to the reactor clarifier. Each of the chemicals is pumped to the raw water only during low lift pump operation. That is, chemical feed pumps start and stop simultaneously with the low lift pump.

The applied dosages of each of the chemicals are based on jar tests performed on Odessa WTP raw water, 1 to 4 times per year. After each jar test and otherwise about once per month, each feed pump is calibrated to the prescribed dosage using a 1000 mL graduated cylinder and a stopwatch. The actual monitored dosage of each chemical is based on the volume of chemical solution used each day and the calculated

daily raw water flow rate. It is important to note that the raw water flow rates are estimated each day, and may not be accurate. The dosage calculation that is recorded each day would therefore not be the actual dosage.

At the time of this study (August 1988), the target alum dosage was 30 to 40 mg/L. The alum feed pump was calibrated monthly to feed at a rate of 65 to 85 mL/min or 43-57 g alum/min to the constant raw water flow rate of 2.05 mL/d.

At this time, the target Aquafloc dosage was 0.3 mg/L of raw water flow. A 0.1 percent solution was fed at a calibrated rate of 300 mL/min to result in a constant dosing rate during low lift pump operation. In order to make up the Aquafloc solution, 0.9 kg of powder is added to 0.9 m^3 of plant supply water, and mixed quickly for 5-10 minutes and slowly for 1 hour. During solution mixing, the low lift pumps are manually kept from operating.

During this study period, the target bentonite clay dosage was 15 mg/L. In order to provide this dosage, the feed pump was calibrated to pump 425 mL/min of a 5 percent clay solution. The clay solution is a mixture of 50 kg of clay with 1 m^3 of plant supply water in the day tank. Constant mixing keeps the solution from separation. Occasionally, a sludge blanket control problem in the clarifier will instigate trial and error measures to be taken at the plant. Typically, the clay addition will be stopped until the problem is brought under control. Subsequently, the normal feed rate will be resumed.

Appendix I, Tables I-1 and I-2 present the historical (1985-1987) dosages calculated based on chemical used and estimated raw water volumes. It should be pointed out that for most of the months, (January-March, May-December 1985, January-July, October-December 1986 and January, February 1987), the plant Utility Monitoring Sheets with this data (Sheet B4-C4) were unavailable. Based on the available data, alum dosages varied between 6 and 94 mg/L of raw water volume. Aquafloc dosages ranged between 0.16 and 0.18 mg/L. Bentonite clay was not added to raw water until 1987. The clay dosage had steadily been increased from 0.3 mg/L in March/April to 11.3 mg/L in October 1987.

The historical chemical dosage data may be very approximate for the following reasons:

- Raw water flow rates were estimated and were often historically recorded as equal to treated water flows (refer to Section B.)

- The weight of chemicals used each day was based on a visual inspection of liquid levels in the chemical tank. In addition to a human error, there may be an error associated with different persons reading the level (i.e. repeatability)

In addition, where historical data was available, dosage rates were often erratic on a day to day basis. In combination with any of the above contributing factors, this was possibly due to an insufficient frequency in feed pump calibrations. In any case, it is obvious that the methods presently used at Odessa WTP for chemical dosing do not provide an adequate degree of dosage control.

D.5 DISINFECTION

A single chlorinator is used for both pre- and post-chlorination. The chlorinator feeds to one water stream which is subsequently divided into two streams. The flow division is controlled by the individual flow controls on each stream. The plant staff aim to maintain a flow division of 90 percent and 10 percent in pre- and post-chlorination, respectively.

For pre-chlorination, a sample of sand filter effluent is analyzed daily for total chlorine residual. A total chlorine residual of 0.8 mg/L is desired.

The post-chlorine dosage is based on the desire to maintain a total chlorine residual in the treated water prior to distribution of 0.8 mg/L. This concentration was established in order to meet the chlorine demand in the distribution system. An online free chlorine residual analyzer on the treated water is available but is not used for chlorine dosage control.

The chlorine dosage rate and flow division is adjusted daily, if necessary, to meet the above guidelines, subsequent to the chlorine residual analyses. The actual chlorine dosage is calculated using the daily weight of chlorine used, the flow division between pre- and post-chlorination and the calculated raw water flow rate.

The resulting applied chlorine concentration data may be considered somewhat approximate, since the applied chlorine concentration in the treated water is based on raw water flow. This method does not take into account that fraction of the raw water flow, including clarifier sludge and backwash wastewater, that exits the plant prior to the post-chlorine application. In addition, the raw water flow volume used for both pre- and post-chlorine dosage calculations is estimated (Section B). Furthermore, the historical data in Appendix IV often shows that measured total chlorine residuals in the treated water are higher than the post-chlorine calculated dosages that were applied. Implications of these results are discussed in Section E.

The historical (1985-1987) pre- and post-chlorine dosages are summarized in Table IV-I, Appendix IV. Also shown is monthly disinfection data characteristic of seasonal variations (Table IV-2). In the period 1985 to 1987, monthly average pre-chlorination dosages ranged from 3.4 to 7.5 mg/L, resulting in monthly average total chlorine residuals in the sand filter effluent in the range of 0.37 to 0.82 mg/L. The pre-chlorination dosages were typically 1 to 2 mg/L higher in the summer months, so that no seasonal variation was evident in the chlorine residual.

Monthly average post-chlorination dosages have ranged from 0.42 to 0.99 mg/L, resulting in total chlorine residuals in the treated water going to the distribution system of 0.4 to 0.75 mg/L. Free chlorine residuals were not recorded on MOE Utility Monitoring System spread sheets in this three year period.

D.6 SAMPLING AND DATA COLLECTION

D.6.a In-Plant Monitoring

Table D-1 presents the parameters analyzed or measured at the plant on a regular basis. This information along with operational information is recorded on a Daily Work Record, shown in Figure D-1. The information is subsequently recorded on the MOE Utility Monitoring System spread sheets (B1, B2, B3, B4-C4, B5-C5) which are sent to MOE at the end of each month. As shown in Appendices I and III, much of this information has not historically been regularly monitored and/or recorded on MOE sheets.

Parameters measured daily in raw and treated water include pH, temperature, turbidity and colour. Treated water and sand filter effluent concentrations of total chlorine residual are also measured daily.

Table D-1
IN-PLANT SAMPLING AND ANALYSIS PROGRAM AT ODESSA WTP

Parameter	Location	Frequency	Instrumentation
Temperature	raw treated	1/day 1/day	Thermometer
Turbidity	raw treated	1/day 1/day	Hach Model 2100A turbidimeter
Colour	raw treated	1/day 1/day	Lovibond colour comparator, Nesselerizer
Total Chlorine Residual	sand filter effluent treated	1/day 1/day	Lovibond chlorine residual kit, DPD tablets
pH	raw treated	1/day 1/day	Lovibond pH kit, colour comparator disk

During a site visit to the plant in August 1988, the methods used at Odessa for measuring turbidity, chlorine residuals, and pH were compared to results from CH2M HILL's equipment. The equipment at the plant produced results for raw and treated water samples that agreed with the CH2M HILL equipment. However, only one standard of 0.64 FTU was available at the plant for calibrating the turbidimeter. More standards covering a broader range of turbidities (0.1 to 3 FTU) should be available to

FIGURE D-1

DAILY IN-PLANT MONITORING SHEET
USED AT ODESSA WTP

Ministry of the Environment
Ontario

Daily Work Record
Odessa Water Plant

Date				
Daily Flow $10^3 m^3$	CL2 Use Kg	Sand Filter CL2 Res. Pre Mg/L	Final CL2 Res. Post Mg/L	Temperature °C

Turbidity Raw	Turbidity Treated	Color Raw	Color Treated

Sand Filter Backwash		Low Lift Total Pumps Total Run		Carbon Filter Backwash
#1	#2	#1	#2	

Work Done

1548 6/84

accurately measure turbidities typical of the raw and treated water at Odessa WTP. It should be noted that the laboratory area was small and unheated. Operational parameters recorded daily at the plant include:

- Raw water flow
- Treated water flow
- Chlorine, alum, clay, Aquafloc used (kg)
- Number of backwashes per sand filter and total wastewater volume
- Carbon filter backwashes and total wastewater volume

D.6.b Routine Sampling

Table D-2 summarizes the ongoing sampling that takes place at Odessa WTP.

Table D-2
SUMMARY OF ROUTINE SAMPLING PROGRAMS AT ODESSA WTP

Program Name	Location of Sample Analyses	Sampled Stream	Frequency of Sampling	Parameters Analyzed
UMIS[1]	Kingston Regional MOE	• Raw water • Treated water	1/month	Colour, pH, conductivity, alkalinity, turbidity, chloride, hardness, Ca, Mg, Fe, SO_4
DWSP[2]	MOE, LSB, Toronto	• Raw water	1/month	Refer to Table I-3
Bacteriological	Kingston Regional MOE	• Raw water • Treated water • 4 locations at extremities of distribution system	1/week	Total coliform, fecal coliform, fecal streptococcus
		Special Clearwell Samples: • Composite bottom & top sample from clearwell	1/3 months	Total coliform, fecal coliform, fecal streptococcus

Notes: [1]MOE Utilities Monitoring System
[2]MOE Drinking Water Surveillance Program

D.7 OPERATOR DUTIES

As noted, there are 3 personnel on duty during an 8 hour work day, who are also responsible for the operation and maintenance of the Odessa WPCP and Amhurstview lagoon and pumping station. Plant staff duties performed by either the Chief Operator, Operator or contract employee include:

1. Administration

2. Plant Operation
   - Response to alarms
   - Maintenance of chemical volumes for treatment

3. General Maintenance
   - General plant upkeep
   - Chemical solution preparation
   - Equipment cleaning, repair, adjustment
   - Seasonal maintenance programs

4. In-plant Monitoring Program
   - Sample collection
   - Lab tests
   - Chemical usage, dosage calculations
   - Documentation of performance parameters

5. Offsite Monitoring Program
   - Sample collection, preservation, packing transport

E. PLANT PERFORMANCE

E.1 FLOW CONTROL

The Odessa WTP operates in an automatic start-stop manner. A transitional period occurs at the start of each operational cycle until the system has regained steady state. This transitional period has historically caused difficulties in controlling the sludge blanket in the reactor clarifier and the desludging operation. Furthermore, this transitional period may also negatively affect the turbidity removal mechanisms in the clarifier, filters and GAC contactor.

In the following subsections, an experimental program to determine the effects of start-stop operation on the various unit processes is presented. Subsequently, alternative methods of reducing the frequency of starts and stops and maintaining continuous operation to optimize plant operation and performance are presented.

E.1.a Reactor Clarifier

Start-stop operation can negatively affect the reactor clarifier turbidity removal ability. Flocculation within the blanket is expected to be poorer during the startup period, and this problem is aggravated if the desludging process is not optimized. If there is too high a solids volume in the clarifier zone, the sludge blanket could rise and escape with the overflow during startup. Alternatively, insufficient solids in the reaction zone,

caused by wasting too large a sludge volume, will result in poor turbidity removal because the blanket is too thin and flow distribution through it during startup is not optimal.

At Odessa WTP, there are complications associated with selecting a desludge frequency and timing. More specifically, the desludge timer automatically resets at the beginning of low lift pump operation and wasting occurs at this time and every set interval after this time. The sludge blanket drops during non-operating periods because of continuous thickening. Therefore wasting of the thickened sludge immediately after plant startup reduces the solids concentration available for the reaction chamber. At too long a wasting period or too frequent wasting, the entire recirculating sludge concentration could be eliminated.

Because of these problems, the plant staff often desludge manually. EIMCO, the reactor supplier, report that manual desludging for an operation of this size and with start-stop operation is the simplest way to maintain complete control of the desludging operation. However, this process must be optimized for the start-stop operation.

In order to optimize the desludging operation at Odessa WTP, a series of experiments to be designed by MOE or a contracted consultant are recommended. The reestablishment of the sludge blanket after plant startup should be monitored at various recirculating solids concentrations to determine how high the blanket rises and also how quickly it reaches its steady state height. In addition, the effects of plant startup on turbidity removal should be monitored during this transitional period.

Specifically, the proposed experimental program involves continuous monitoring of the sludge level in the clarifier for the period beginning at plant startup and until the sludge blanket reaches its steady state level. This can be done by taking samples of the clarifier contents at regular intervals at the three existing clarifier sampling points and performing 5 minute settling tests.

Simultaneously, turbidities in clarified water samples taken at 2 to 3 minute intervals (or continuously) should be determined. These tests should be performed over 6 to 10 restart cycles in different periods of the year and repeated once the desludging operation is optimized.

The results of each of the tests will establish the following:

- A relationship between sludge blanket height versus time after startup.
- A relationship between sludge concentration in the clarifier versus steady state sludge blanket height.
- A relationship between clarifier effluent turbidity and time after startup.
- A relationship between effluent turbidity and sludge concentration and height.

A detailed experimental protocol should be prepared by MOE or a contracted consultant. Interpretation of the data and recommendations toward ongoing experimental programs required to optimize clarifier performance should be made by MOE or the consultant.

E.1.b Filters and GAC Contactors

The sand filters and the GAC contactor both function as filters for turbidity removal. During low lift pump operation startup, there is a possibility that light floc on the filter is stripped through the filter by the initial hydraulic surge. This would cause the initial filtered water turbidity to be high. After the initial surge, the turbidity would probably improve.

There is insufficient monitoring data at the Odessa WTP to determine if the hydraulic surge on the filters or contactors is degrading treated water turbidity. It is therefore recommended that a sampling program that will measure the effects be undertaken. Again, detailed protocol and interpretation of the experimental results should be carried out by MOE or a contracted consultant.

The proposed sampling program involves the monitoring of turbidity levels in filter and GAC contactor effluent immediately after low lift pump operation and at regular intervals (2 to 3 minutes) or continually until filter effluent turbidities reach steady state. Tests should be repeated for 6 to 10 start cycles on the filters and GAC contactor at different times of the year.

The results of these experiments will be used in conjunction with the reactor clarifier results to select a methodology to control flows and optimize plant performance.

E.1.c Alternatives for Flow Control

Once the effects of start-stop operation on clarifier, filter and GAC contactor performance have been established, options for modifying the plant to optimize performances must be considered.

If the results from all of the tests show that there is no variance in turbidities in any of the process effluents, and sludge blanket control can be optimized, it is recommended that no changes take place in the automatic operation of the plant.

The most likely scenario is that the experimental program will reveal negative effects on treated water turbidities as a result of start-stop operation. In this case, optimization will involve reducing the frequency of low lift pumps starts, accomplished by increasing the length of operating intervals. This is a difficult option at the Odessa WTP because of the limited volume of treated water storage area in the clearwell and tower. The following alternatives may be evaluated:

1. The simplest way to lengthen the pump operational intervals is to throttle the low lift pump to decrease the flow to the plant. In 1986 and 1987 the maximum observed daily raw water flow (with one exception) was 1.5 ML/d in summer months and 1.0 ML/d in winter months. This indicates that the pumps could be throttled to 75 percent capacity in summer and 50 percent capacity in winter, to lengthen the operational periods by 33 and 50 percent, respectively.

   Each time the throttling is adjusted, the chemical feed pumps and chlorinator will require recalibration. The primary disadvantage to this alternative is the increased energy consumption of operating the pumps for more hours of the day without reducing the power consumption.

2. Another way to improve the flow control operation is to implement a continuous flow system. A continuous flow configuration would require the following:

   - Variable speed drives on the low lift pumps, remotely indicated by a continuously monitoring level meter in the treated water clearwell
   - A magmeter flow meter on the raw water discharge pipe
   - Analog to pulse converters to send a signal to the chemical feed pumps and chlorinators to flow pace feed rates. New chemical feed pumps may also be required

   The major disadvantage of this system would be the capital costs. However, the operating and maintenance costs would not be higher than for the existing system.

3. The most costly alternative is to provide additional clearwell storage volume. As discussed later, this may also be required for sufficient disinfection. This alternative would allow an increased operating volume in the clearwell, thereby lengthening low lift pump operating periods.

E.1.d Summary of Recommendations

Prior to optimization of the flow control methods used at the Odessa WTP, it is recommended that the effects of the present start-stop operation be established. It is therefore recommended that an experimental program be undertaken to:

- Determine the effects of low lift pump startup on turbidity removal performance of the reactor clarifier, filters, GAC contactor and the treated water turbidity levels.
- Determine the sludge blanket behaviour in the clarifier during plant startup, and optimize the desludging operation.

If the experimental program results indicate that turbidity removal performance if poor for an interval after plant startup, then it is recommended that the following alternatives to reduce the number of starts be evaluated:

1. Throttle low lift pumps in the discharge line to reduce the raw water flow rate.

2. Implement a variable speed, continuously operating low lift and chemical feed pump operation, controlled by a continuously monitored treated water clearwell water level.

3. Provide additional clearwell storage volume.

It is recommended that the costs and benefits of each of the above alternatives be evaluated in detail by the MOE in conjunction with a consultant, once the effects of start-stop operation on plant performance has been determined.

E.2 TURBIDITY AND COLOUR REMOVAL

E.2.a Historical Performance

As discussed in Section A., the raw water treated at Odessa WTP contains very low turbidity, usually less than 2 FTU. However, high colour levels are characteristic of the raw water. Therefore, chemical treatment of raw water at Odessa WTP is primarily aimed at reducing the colour to acceptable levels (5 TCU) in treated water.

Table E-1 presents the historical colour levels in treated water. Since 1987, treated water colours exceeded the Objective level in many samples, including 60 percent of the 1988 DWSP monthly samples. It can be surmised that the coagulation process has not been optimized for colour removal.

Table E-2 presents the historical raw water and treated water turbidities at the Odessa WTP. As shown, turbidity levels have generally been below the MOE Objective level of 1.0 FTU. However, levels infrequently exceeded this limit in the past few years. In addition, maximum monthly averages were greater than 0.7 FTU for all years of available data. Filter effluent turbidities for a well operated plant should be much below 1 FTU. Furthermore, residual aluminum concentrations in 1988 DWSP treated water exceeded the Guideline level of 0.1 mg/L in 70 percent of samples. This confirms that the turbidity removal process has not historically operated as well as it could be.

Optimization of the colour and turbidity removal process at the Odessa WTP will involve optimization of the chemical dosages and mixing, as well as of the performance of the clarifier, filter and GAC contactor. It should be noted that flow control will play a major role in optimization of these processes.

E.2.b Chemicals for Coagulation

Low turbidity levels, characteristic of Odessa WTP raw water, result in a water that is difficult to coagulate, since there is insufficient surface area for the surface reactions to occur and there are insufficient solids to promote good flocculation and the formation

Table E-1
SUMMARY OF TREATED WATER COLOUR LEVELS AT ODESSA WTP

Period	Colour (TCU)							
	Minimum Day	Maximum Day	Minimum Monthly Average	Maximum Monthly Average	Monthly Averages			
					January	March	July	October
1985*	5	5	5	5	5	5	5	5
1986*	5	11	5	5	5	5	5	5
1987	<5	14	<5	5.8	5.1	5	5	5
1988 (DWSP)	<1.0	16.5	-	-	-	-	8.5	16.5

*There is little confidence in the accuracy of this data, since 5 TCU was recorded for all days.

Table E-2
SUMMARY OF HISTORICAL TREATED WATER TURBIDITIES AT ODESSA WTP

Period	Turbidity (FTU)							
	Minimum Day	Maximum Day	Minimum Monthly Average	Maximum Monthly Average	Monthly Averages			
					January	March	July	October
1985	0.25	1.2	0.4	1.0	0.51	0.66	0.79	0.64
1986	0.35	0.90	0.42	0.82	0.57	0.43	0.64	0.40
1987	0.15	1.1	0.41	0.70	0.51	0.48	0.47	0.51
1988 (DWSP)	0.30	1.0	-	-	-	-	0.65	1.0

of a dense floc. Two options are available to overcome this problem: elevated coagulant dosage or the addition of solids such as the hydrophobic bentonite clay currently in use. The latter option will usually result in reduced doses of coagulant and may promote the removal of other colloids, such as colour.

At the Odessa WTP, bentonite clay is used for improved coagulation and colour removal. On August 12, 1988, jar tests were performed on the plant water to determine the doses of alum, coagulant aid (Aquafloc) and bentonite that would optimize the process. Details of the experimental protocol are presented in Appendix V.

The raw water quality used for the tests was:

pH:	7.7
Colour:	5.0 TCU
Turbidity:	1.1 FTU
Dissolved Organic Carbon (DOC):	9.9 mg/L

Because the jar testing was done on a low colour raw water, the chemicals could not be optimized for colour removal. The available instrumentation for measuring colour was not reliable below 5.0 TCU.

Table E-3 presents a summary of the jar testing results. The turbidity removal efficiency performance was best in Jars 8 and 12, corresponding to respective alum dosages of 25 and 30 mg/L, Aquafloc dosages of 1.0 and 1.2 mg/L and clay dosages of 13 and 8 mg/L. This compared to the actual plant dosages at that time of 35 mg alum/L, 0.3 mg Aquafloc/L and 15 mg bentonite/L. It can be seen that the increased Aquafloc dosage allowed for a reduced alum and bentonite dosage. The floc in both jars were large and demonstrated very good resistance to hydraulic transients, as indicated by manually shaking the jar with settled floc.

As shown on Table E-3, dissolved organic carbon (DOC) removal was less than 22 percent for all jars. At the present time, optimization of Odessa WTP is based on turbidity removal. However, if at some future date TOC and DOC removal performance must be optimized, evaluation of alternative chemicals by jar testing should be undertaken.

The overall conclusion from the jar testing was that the Aquafloc dosage at Odessa WTP was not sufficient to produce a strong settleable floc and remove turbidity. The test results did indicate that the plant dosages of alum and clay were within a range found to be reasonable during jar testing.

The dosage results of these tests should not be considered conclusive, since they were executed on one sample that did not have the characteristic high colour of the raw water. It is recommended that jar tests be repeated on the raw water according to the MOE Jar Testing Protocol prior to changing the present dosages. Also, jar tests should be repeated at least four times per year (seasonally) as well as when deterioration in

Table E-3
JAR TESTING RESULTS FOR ODESSA WTP RAW WATER
(August 25, 1988)

Jar	Alum Dosage (mg/L)	Aquafloc Dosage (mg/L)	Bentonite Dosage (mg/L)	Final pH	Turbidity (FTU)	DOC (mg/L)	Floc Size[1]	Floc Density	Resistance to Hydraulic Transients[3]
1	20	0.2	3.0	6.8	1.7	10.0	small	dense	poor
2	30	0.2	3.0	7.0	1.6	8.5	medium	light	poor
3	20	1.0	3.0	7.0	1.5	10.3	small	light	good
4	30	1.0	3.0	7.1	1.3	9.4	large	light	poor
5	20	0.2	13	7.1	1.3	8.8	large	light	poor
6	30	0.2	13	7.1	1.3	8.5	medium	dense	poor
7	20	1.0	13	7.2	1.5	9.4	large	dense	very good
8	30	1.0	13	7.1	1.0	7.8	large	light	very good
9	14	0.6	8.0	7.1	1.4	9.7	small	dense	poor
10	36	0.6	8.0	6.8	1.5	8.9	medium	light	poor
11	25	0.0	8.0	6.9	1.7	9.6	medium	light	poor
12	25	1.2	8.0	6.9	1.0	9.0	large	medium	very good
13	25	0.6	0.0	7.0	1.5	9.0	medium	dense	moderate
14	25	0.6	16	7.0	1.3	8.8	medium	dense	good
15	25	0.6	8.0	6.9	1.7	9.0	small	light	poor
16[2]	35	0.3	15	7.0	1.4	9.9	medium	light	moderate

[1] small: 1-2 mm, medium: 2-5 mm, large: 4-6 mm
[2] Dosages used at the plant in August 1988.
[3] Demonstrated by gently shaking jar containing settled floc.

the clarifier performance indicates. Optimization of the chemical dosages should be based on both turbidity and colour removal performance.

During the jar testing, optimization of aluminum residual concentrations by pH adjustment was not considered. It can be expected that optimization of the chemical dosages and turbidity removal performance will also reduce the aluminum residuals to below the historical levels. However, if the aluminum residual levels continue to be higher than the 0.1 mg/L Guideline level, pH adjustment should become a factor in optimization of the chemical process by jar tests. It has been shown that turbidity and colour removal with alum is most effective at a pH of about 6. If pH adjustment is required for Odessa WTP raw water, a day tank, feed pump and application point will be required for the acid solution (sulphuric acid). In addition, lime or soda ash addition to treated water would be necessary to control corrosivity.

Process monitoring of the chemical dosage process should involve three actions:

1. Regular calibration of the chemical feed pumps to ensure that the target dosage is being met (3-4 times/week).

2. Regular measurement of clarifier effluent and final effluent residual aluminum concentrations.

3. Jar testing (according to MOE Jar Testing Protocol) at least four times per year, or when clarified water colour or turbidity deteriorate or aluminum residuals in treated water increase. Colour removal, turbidity removal and aluminum residual should be optimized using four variables: alum dosage, Aquafloc dosage, bentonite dosage and, if necessary, pH levels.

It is important to note that while the jar tests can indicate an appropriate dosage combination, they cannot simulate the reactor clarifier performance. In the reaction chamber, the turbidity removal is by solids contact with a large concentration of solids. Since this situation can not be easily scaled down for laboratory testing, jar testing is an alternative control process.

E.2.c Chemical Application Points and Rapid Mixing

At Odessa WTP there is no rapid mixing process. The calculated energy gradient values for flash mixing in the pipe to the reactor chamber are an order of magnitude less than typical quoted effective values. However since the reaction chamber provides slow mixing of raw water with chemicals with a high density of flocculated recirculating solids, the additional benefits of energy input from a flash mixing unit are unknown.

At the Deseronto WTP, a similar mixing and reactor clarifier configuration is utilized. However, at that plant, an in-line electric mixer does exist. CH2M HILL has recommended that an experimental program to determine the benefits of rapid mixing be executed. If this program shows that turbidity removal in the clarifier or filter process can be improved with rapid mixing, then these results should be applied to the

Odessa plant, and methods for providing additional mixing of raw water with chemicals should be investigated.

Alternatives for additional energy input to the raw water with chemicals are:

1. Installation of an in-line electric mixer on the underground pipe leading to the reactor clarifier.

2. Installation of a static mixer on the same pipe. The alternative may not be feasible because the low lift pumps may not provide enough energy to overcome the head loss through the mixer.

3. Chemical addition points could be moved to the intake side of the pipe so that mixing is provided by the low lift pumps. This alternative would require construction of a weir within the wet well where chemical could be added at the intake. It should be noted that this alternative is not recommended by the MOE Design Guidelines and should only be considered as a last resort.

E.2.d Coagulation, Flocculation and Settling

As discussed in Section E.1, tests are recommended to determine how well the reactor clarifier unit is suited to the start-stop operation of the plant. Optimization of the process for turbidity removal will therefore involve optimization of the plant flow control methods. Further optimization of the reactor clarifier operation will result from optimization of chemical dosages and rapid mixing.

The turbine speed used for slow mixing and recirculating of solids was set in 1979 after a number of trial and error tests. Once the chemical dosages and rapid mixing processes have been optimized, turbine speed may also require adjustment. The ideal turbine speed setting will be slow enough to provide good flocculation through mixing and particle collision without shearing floc, and fast enough to provide good recirculation of sludge solids to maintain a high concentration in the chamber. An experimental procedure designed by MOE or the consultant should be followed to allow for an orderly evaluation of performance at various speeds.

The experimental procedure will involve running the turbine at various speeds. At each speed, the plant should operate for a minimum of 12 hours prior to sampling. Turbidity levels in clarifier effluent should be measured at regular intervals over an entire period of low lift pump operation. Concurrently, the recirculating sludge should be sampled through the sampling tap at regular intervals over this period and 5 min sludge settling volume be determined. The procedure should be repeated for a wide range of speeds. The results can be used to establish a relationship between turbidity removal performance and turbine speed and between turbine speed and sludge concentration in the reaction chamber. Based on the results interpreted by MOE or the consultant, the turbine speed should be adjusted.

Sludge Blanket Control

Control of the sludge blanket to buffer the start-stop operation of the Odessa WTP was discussed in Section E.1. Optimization of the desludging operation will result in a desludging frequency that will prohibit the blanket from rising above a high level and escaping over the effluent weir. Also, enough sludge will be kept in the solids reaction chamber for solids contact.

The speed of the rake arm and scraper was set in 1979. Since the scraper is operating in a normal velocity range for this type of process, it is not recommended that re-evaluation take place at this time. However, the plant staff, MOE or the consultant may want to consider experimenting with the speeds once all other factors have been optimized.

Process Control

A significant problem associated with controlling the reactor clarifier operation has historically been that there was no routine performance monitoring. In the past the plant staff has relied on visual examination of the clarified water and treated water turbidities.

If the plant staff maintain a continual awareness of the clarifier performance, chemical dosage re-evaluation needs will be identified with changing water quality. In addition, the clarified water turbidities effect filter operation and should be monitored for this reason. It is therefore recommended that the clarified water turbidity be monitored on a routine basis. The most accurate and effective technique used to routinely monitor turbidity is using an online turbidimeter with a recorder. This will allow around the clock monitoring of clarifier performance without requiring significant manpower. In addition, the continuous record will allow the experimental program recommended for the evaluation and optimization of flow control methods to be carried out with ease.

It is recommended that the plant staff control the desludging operation using daily 5 minute settling test results done on sludge from the recirculating chamber. This technique has proven effective at the Deseronto WTP in setting the desludge frequency and interval.

Because the plant operation will continue to be automatic, it is also recommended that significantly degrading reactor clarifier performance be alarmed. That is, the turbidimeter should be connected to alarm at a high turbidity level. A timed delay should be incorporated so that short term slugs will not activate the alarm.

E.2.e Sand Filters

Media and Backwashing

In 1988, visual inspection of the sand in the filters show extensive blackening, as well as a wide interspersion of mudballs. The following steps are recommended to improve the condition of the existing sand:

- Sieve analysis of existing medium. If the medium is within an appropriate size range, then it should be removed and cleaned thoroughly. If the size is not appropriate, or cleaning cannot be accomplished, sand of suitable size should replace the existing medium.

- The backwashing has not been adequate at Odessa WTP, as indicated by the condition of the sand. The filter manufacturers, Degremont, report that a surface auxiliary wash system can be implemented in these units. Therefore, a surface wash system, such as a fixed nozzle spray system, should be augmented when the medium is out of the filters. The analog filter controller instrumentation will require modifications so that surface washing becomes part of the automatic backwash cycle.

- Repair of malfunctioning or clogged floor drain nozzles.

Because dual media filters are reported to provide a higher quality effluent than sand alone, replacement of the existing sand media with sand and anthracite was considered by CH2M HILL. However, Degremont report that this option is not available for this type of filter unit.

Filtering

The effects of start-stop operation on turbidity removal in the dual media filters was discussed in Section E.1. Once the surge effects on the filters has been determined, a number of alternatives that were presented in this section can be considered for reducing the number of starts at the plant.

In order to optimize filter operation, three other factors require consideration. These include:

- The terminal head loss setting

- The surge effect of a clean filter coming online after backwashing

- The surge effect of the high flow rate through one filter while the other filter is backwashing

It is recommended that an experimental program, designed by MOE or the consultant, be carried out to monitor the filtered water turbidity levels in both filters over a number of low lift pump operational cycles. The monitoring should continue over six to 10 backwash cycles. Interpretation of the results and subsequent modifications should be done by MOE or the consultant.

If there is an increase in turbidity levels prior to backwashing, the terminal head loss setting of 1.52 m should be decreased. The experiments should be repeated until the head loss setting instigates a backwash prior to turbidity breakthrough.

The experimental program results may show that there is a slug of highly turbid water exiting the filter immediately after backwashing and coming back online. These filters do not have the ability to filter to waste. Therefore, without major modifications to the design of the unit, this problem will exist. Therefore, the GAC unit must be depended on as an integral part of the turbidity removal process.

The doubled rate of filtering through one filter while the other is backwashing may result in washing the solids through the media and into the filtered water. In order to prevent this, three alternatives can be considered:

- Stopping low lift pump operation for the duration of the backwash cycle (about 6 minutes). If terminal head loss is reached when the clearwell is at a low level, the shut down during the backwash cycle time may result in a low level alarm. Therefore, for this alternative to be considered, a volume of 8.5 m^3 must be allowed between the low level switch that starts the low lift pumps, and the alarm level. This option increases the number of plant starts and stops, which may worsen the situation.

- Reconfiguration of the piping so that the total plant flow of clarified water is actually used to backwash the dirty filter and never exits to the GAC contactor. This would cause a slight increase in the average backwashing velocity up to 123 m^3/h compared to 98 m^3/h, but a decrease in the maximum backwashing rate (because the present system is declining rate). This option will require a complete engineering design and hydraulic analysis.

- Dependence on the GAC contactor for turbidity removal during turbidity surge periods. This option is the simplest, but also means more frequent GAC backwashes, requiring more manpower and more water.

E.2.f GAC Contactors

The GAC Contactor was installed at the Odessa WTP for taste and odour removal. However, since this process also has a capability to remove turbidity and may be necessary for good quality plant effluent, it should also be considered an integral part

of the turbidity removal process. The following subsections present the recommendations for optimization of the GAC contactor for turbidity removal performance.

GAC Media

The GAC presently in the contactors is Filtrasorb 400, with effective size according to the manufacturer, of 0.65 mm. The size of this medium is within an acceptable range for turbidity removal.

Because chlorine has been known to accelerate the disintegration of GAC, it is recommended that the medium bed height be checked every 6 months for depth and topped up with new medium if necessary.

Filtering Operation

Determination of terminal head loss pressure that signals the need for backwashing is critical to the optimization of the GAC contactor for turbidity removal.

A proposed experimental program will involve characterization of the turbidity profile in the GAC effluent over a number of intermediate operational cycles. The terminal head loss as measured on the intermediate pump discharge pipe pressure gauge will be established at turbidity breakthrough. The experiments should be repeated 3 to 5 times.

It is recognized that there may be a turbidity surge effect due to intermediate pump startup. However, because the GAC operation is manually controlled, there are no simple options available to reduce this effect. The best way to improve the GAC contactor effluent turbidity is to reduce the loading to this unit. This will be done in the optimization of chemical dosages, reactor clarifier and sand filter operation.

It is recommended that process control for turbidity removal be based on continuously monitored turbidity levels from in-line turbidimeters on each GAC contactor. These records should be examined daily by plant staff. In addition, the pressure gauge on the contactor should be alarmed to activate when head loss in the filter is approaching the terminal level.

GAC Contactor Backwashing

Based on the GAC manufacturer data, and the condition of the medium in January 1989 (i.e. no mudballs, etc.), the backwashing rate used is sufficient. A methodology used to determine backwash length at Deseronto WTP, of examining backwash water in clear plastic tubing, has proved to be effective. A simple system like this could also be used at Odessa WTP.

E.2.g Summary of Recommendations

Recommendations made to optimize the turbidity removal performances of the various unit processes are the following:

- It is recommended that jar testing using MOE Jar Testing protocol be carried out seasonally (quarterly) to optimize chemical dosages for maximum colour and turbidity removal.

- It is recommended that the Deseronto WTP experimental program results for rapid mixing be used to determine the need for rapid mixing at Odessa WTP.

- An online turbidimeter with recorder and high level alarm on the clarified water stream is recommended for turbidity monitoring and process control.

- It is recommended that 5 minute sludge settling tests performed on reaction chamber slurry be used to control the desludging operation.

- It is recommended that the filter sand be cleaned and replaced if necessary.

- Visual inspection and core samples and sieve analysis of media in the filters is recommended annually to indicate backwashing effectiveness and other media problems.

- It is recommended that an auxiliary media surface wash system such as a fixed nozzle spray system be installed in each filter.

- An experimental program is recommended to optimize the terminal head loss in the sand filters. In addition, the program will be used to determine the surge effects of double flows in one filter during backwashing and effects of a clean filter coming online.

- It is recommended that in-line turbidimeters with recorders be installed to monitor sand filter effluent streams, and records be examined daily by plant staff.

- Visual inspection of the sand filter backwash water on a quarterly basis is recommended to ensure that the backwash cycle is of sufficient length.

- It is recommended that the GAC contactor be considered an integral part of the turbidity removal process, and therefore is equipped with a turbidimeter with recorder on the contactor effluent stream for process monitoring and control.

- An experimental program is recommended in order to determine terminal head loss and backwashing frequency of the GAC contactor for optimal turbidity removal performance.

E.3 TASTE AND ODOUR REMOVAL

E.3.a Dioxin/Furan Compounds Detected on GAC Media

The GAC contactors at both Odessa WTP and Deseronto WTP had been in service for about seven years when it was decided in October 1987 that the media be replaced. At this time, a MOE Water Resources Branch/SE Region joint research study was initiated to investigate the kinds of substances that might be retained in GAC contactors after a long period of service. Samples of the GAC media were collected and taken to MOE Laboratory Services Branch for organic and inorganic characterization. Although no recognized standardized analytical protocol existed for GAC media, the carbon removed from each of the contactors at both WTPs was analyzed for dioxin.

Analytical results from the first samples (October 1987) showed that various dioxins and furans could be detected on the carbon. Tetrachlorodibenzodioxins were present at the highest concentrations. However, no 2,3,7,8-tetrachlorodibenzodioxin was found. The levels of total dioxin/furan compounds were less than those typically detected in Ontario soils.

On January 6, 1988, additional samples of unwashed GAC media were collected for further analyses. Due to the increased sensitivity of the analytic equipment, enabling lower detection limits, congener groups were detected at this time that were not found previously. However, although confirmed present, concentrations were so low (10^{-12} g/g range) that levels of these additional compounds could not be quantified. The tetrachlorodibenzodioxin concentrations were similar in this test to the previous tests.

Subsequent to the media analysis, samples of unused GAC media, raw and treated water (January 22, 1988), and GAC backwash water (January 22, 1988) were collected and analyzed for dioxin/furan compounds. None of the compounds were detected in any of these samples from either plant above the detection limits.

Based on the experimental results it can be concluded that dioxin/furan compounds were present on the GAC media. However, results indicate an extrapolated possible worst case for tetrachlorodibenzodioxin concentration in raw water of approximately 10^{-12} g/L, which is well below the proposed interim maximum acceptable concentration (IMAC) for drinking water. Therefore levels in treated water with GAC treatment would be substantially less than the IMAC level.

There are two possible reasons for the presence of dioxin/ furan compounds on the GAC media. The first is that the compounds are present in raw water, either from a natural non-industrial source or from an industrial source. Although some dioxins are naturally occurring (such as octachlorodibenzodioxin) tetrachlorodibenzodioxin compounds, if in the raw water, are contributed from other sources because they are

not known to be naturally occurring. One argument against this theory is that the Odessa WTP receives its water supply from a small creek, with no upstream, industrial contributors. Furthermore, raw water samples from both plants did not contain dioxin/furan compounds above the detection limit. This argument should be used with caution because the database is very limited (i.e. based on one sample from each plant). There remains open the possibility that the presence of dioxin/furan compounds in raw water is episodic. Nevertheless, based on the available information and engineering judgement, it is not likely that these compounds were of industrial or natural origin.

This leads to a second possible explanation, that is, the compounds were formed on the GAC media. A number of researchers have studied the reaction of free chlorine with adsorbed compounds on GAC media. In one study, free chlorine was found to react readily with a group of adsorbed phenolic compounds to produce a number of compounds, including PCBs, that would not be formed in solution (Ref. 4). In another study (Ref. 5), free chlorine reactions with organics on the GAC resulted in formation of hydroxylated PCBs. These studies suggest that there is a possibility for the formation of other compounds such as dioxin under the same conditions. At Deseronto, a pre-chlorination process existed until mid-1986, while at Odessa, pre-chlorination is ongoing.

However the compounds came to exist on the media, the significance of their presence to health is of utmost concern. To evaluate the health risk, it must be known whether the compound that either entered the contactors or were formed within, can pass through into the treated water. One study (Ref.6) showed that many compounds formed on GAC media were strongly adsorbed (e.g. 4-4'-dihydroxybiphenyl), whereas other products (e.g. p-benzoquinone) were displaced by the introduction of a more strongly adsorbed compound. Dioxin/furan compounds are known to be highly insoluble and hydrophobic. For example, 2,3,7,8-tetrachlorodibenzodioxin has a solubility of 2.05×10^{-5} mg/L and K_{ow} of 6.64 (greater than 5 indicates very hydrophobic) (Ref. 7). This suggests that at least the dioxin compounds are strongly adsorbed to the GAC media and would not likely be present in either backwash water or treated water.

We recommend an experimental program to test the following two hypotheses:

1. The dioxin/furan compounds were formed on the GAC media through a reaction between free chlorine and adsorbed organic molecules.

2. The dioxin/furan compounds are strongly adsorbed to the GAC media, and will not be released to the treated water.

To confirm the first hypothesis, homogenous samples of the GAC media from both contactors at Deseronto and from the Odessa WTP contactor, should undergo dioxin/furan analyses. Deseronto WTP has not had pre-chlorination of raw water since before the seven year old GAC was replaced with new GAC, but Odessa has continued

pre-chlorinating. If the hypothesis were true, dioxin/furan compounds would only be present in the GAC media from Odessa WTP.

The second test would involve analyzing the dioxin/furan compounds at various depths in a core sample of the media. It is recommended that a core samples of the media be taken, and divided into 3 or more layers. Each layer should be analyzed separately. If the results indicate that dioxin/ furan compounds are found only in the top layer, or they are much higher in the top layer than in succeeding layers, it is likely that the compounds remain adsorbed to the original solid to which they are attached, however, they enter the adsorber. If, however, the concentrations are homogenous over the media bed or higher in a lower layer, it would suggest that the compounds are moving through the contactor and can pass into the treated water. The rate of this movement however, may be so slow that desorbtion of compounds into treated water may only occur after a number of years.

Based on the results from both Deseronto and Odessa GAC media analyses, a re-evaluation of the role of GAC at Odessa WTP should be made. Consideration should be given to the level of dioxin/furan type compounds that might appear in treated water if the GAC is not used compared to the levels that might be present, if any, when GAC is used. Consideration should also be given to the pretreatment processes that might affect its performance. If dioxin/furan compounds are in the raw water and they are adsorbed, a seven year replacement frequency may be too long. If these compounds are shown to be formed by chlorine-adsorbed compound reactions on the GAC surface, dechlorination, with sulphur dioxide prior to GAC, for example, may be necessary if pre-chlorination is ever to be reinstituted.

E.3.b GAC Contactor Process Control

As previously described in Section C., the media, surface loading rates and empty bed contact time and design flows are appropriate for taste and odour removal at Odessa WTP.

At present, there are no formal process control methods used to determine when the GAC media has exhausted its capacity for taste and odour removal. If a problem does occur in the treated water quality, then plant staff is informed by telephone calls from the resident who perceives the problem.

Replacement of the media in 1988 was not instigated by taste and odour breakthrough into treated water. Therefore, the lifespan of the media for effective taste and odour removal is unknown. In order to optimize the taste and odour removal process it is recommended that process control measures be initiated.

The TOC levels in filtered water and GAC treated water were considered as control parameters. However, because the GAC loses its ability to remove TOC long before its taste and odour removal capability is exhausted, this option was ruled out.

Another alternative was the use of iodine adsorption numbers as process control parameters. This would involve measurement of iodine numbers on clean GAC media, and on GAC samples taken from the adsorber throughout its life. Subsequently, a relationship would be developed between the iodine number and threshold odour over a long-term. Using the correlation, the remaining life of the GAC at any time could be determined by measuring the iodine number on a media sample. This alternative was deemed inappropriate for the Odessa WTP. The long life span of the media would not allow a useful application of process control for many years. In addition the level of effort required from plant staff does not warrant this method.

The process control method most applicable to Odessa WTP involves measurement of threshold odour numbers. To detect deteriorated odour removal efficiency, threshold odour numbers should be established by a selected panel of not less than 3 individuals at seasonal intervals (quarterly). Tests should be conducted at a location away from the WTP site, and in accordance with the methods described in Standard Methods (Ref. 8). If threshold odour numbers indicate ineffective odour removal, GAC media should be replaced.

E.3.c Summary of Recommendations

In order to confirm that there is no health risk associated with the presence of dioxin/furan compounds found on GAC media samples taken in January, an experimental program is recommended that will:

- Determine whether the compounds are formed on the GAC media as a result of a free chlorine reaction with adsorbed organic substances.
- Determine whether the dioxin/furan compounds have potential to desorb from the media and release into treated water.

In order to optimize the taste and odour removal process, it is recommended that process control measures be initiated. That is:

- Quarterly threshold odour number measurements by a panel of 3 or more individuals.

E.4 DISINFECTION

E.4.a Historical Performance

The bacteriological testing results for 1985 to 1987 are presented in Table II-1, and for 1988 (DWSP) are presented in Table II-2, Appendix II. The historical data show that all treated water samples, as well as distribution system samples, were absent of coliform. These data indicate that disinfection has been sufficient to reduce the bacteria levels in treated water to the MOE Objective levels.

The disinfection data presented in Appendix IV is summarized in Table E-4. As shown, a total chlorine residual of greater than 0.1 mg/L was maintained in filtered water since 1986. All treated water samples had a residual greater than 0.1 mg/L. In addition, a free chlorine residual greater than 0.1 mg/L was present in all 1988 and treated water distribution system samples.

Table E-4
SUMMARY OF TOTAL CHLORINE RESIDUAL CONCENTRATIONS IN ODESSA WTP FILTERED WATER, TREATED WATER AND DISTRIBUTION SYSTEM

Year	Total Chlorine Residual (mg/L)							
	WTP				Distribution System			
	Filtered Water		Treated Water		Standing		Free Flow	
	Minimum Day	Maximum Day	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
1985	0.2	1.5	0.3	1.0	-	-	-	-
1986	0.2	1.5	0.2	1.0	-	-	-	-
1987	0.1	1.0	0.1	1.0	-	-	-	-
1988	-	-	0.3	1.9	0.1	1.9	0.3	0.1
1989 (free)	-	-	0.2	1.5	0.1	1.9	0.1	1.9

E.4.b Pre-chlorination

A pre-chlorination process is critical to the operation of the Odessa WTP due to the very short retention time in the effluent clearwell. Therefore, the retention time in the plant must be used to ensure sufficient chlorine contact time for disinfection.

It is recommended by EPA (Ref. 9) that disinfection provide a minimum of 3 log (99.9%) removal of Giardia cysts and 4 log (99.99%) removal of enteric viruses. It can be assumed that well operated plants can achieve a minimum 2 log (99%) removal of Giardia and 1 log (90%) removal of enteric viruses in the turbidity removal processes. Therefore, for 1 log removal of Giardia cysts and 2 log removal of enteric viruses in the pre-chlorination process, the following Ct values are required for the range of raw water quality at the plant, and a 0.1 mg/L residual in filtered water going into the GAC contactor:

Temperature	Ct at pH 7.3	Ct at pH 8.5
0°	7.9 mg/L · min	112 mg/L · min
26°	14 mg/L · min	20 mg/L · min

There is an average hydraulic retention time of 96 minutes in the wet well, clarifier and filtering processes. The actual contact time is recommended by EPA to be the time required in a tracer test for 10 percent accumulation of tracer breakthrough in the effluent. Since the processes are plug flow, 50 percent of the average time or 48 minutes was considered to be a fairly conservative estimate of contact time. Therefore, in the worst case conditions of low temperature and high pH, a minimum free chlorine level of 2.4 mg/L is required. This compares to historical dosages in the range of 3.4 to 7.5 mg/L.

More specifically, these results show that sufficient disinfection can be achieved at chlorine dosages that result in a free chlorine concentration of about 2.4 mg/L in colder months and about 0.4 mg/L in summer months. It should be noted that the chlorine demand exerted by hydrogen sulphide or ammonia in anaerobic or anoxic raw water conditions will require this total chlorine dosage to be increased to maintain the free chlorine level.

E.4.c Post-chlorination

As previously discussed, chlorine dosage is controlled to maintain a target total residual chlorine concentration of 0.8 mg/L to meet the demand in the distribution system. For a conservative approach, it is assumed that an additional 0.5 log (68%) Giardia cyst removal should be achieved in post-chlorination. This will allow a buffer for days with low temperature, high pH, raw water, and post-chlorination is insufficient. The required Ct values for post-chlorination are:

Temperature	Ct at pH 7.3	Ct at pH 8.5
0°C	45 mg/L · min	74 mg/L · min
26°C	8 mg/L · min	11 mg/L · min

The effluent clearwell provides an average of 20 minutes retention time. Taking into account mixing and short circuiting in this tank, a generous estimate of 10 minutes was assumed as the actual hydraulic retention time (for 10% tracer accumulation in the effluent). This shows that at low temperature conditions, high chlorine dosages of 4.5 to 7.4 mg/L are required. This situation is not possible at Odessa, as it would result in very high chlorine residuals entering the distribution system. Because of the small area of town, it is assumed that the retention time in the distribution system is minimal.

These results show that the retention time at the plant, may not be sufficient for the recommended disinfection for Giardia. At Odessa, this is especially critical because of the potential fecal contamination of raw water by a large beaver population. It should be noted that this evaluation is very conservative for the existing situation. At present, the plant does not operate 24 hours per day; therefore there is a much higher average retention time in the clearwell than 20 minutes. Furthermore, the historical bacteriological results do not show any evidence of poor disinfection despite a fairly

high raw water fecal coliform population. If however, operating periods are lengthened or plant flows increase, the nominal clearwell retention time will apply to some portions of the flow and adequate disinfection must be ensured.

It is therefore recommended that MOE or a consultant carry out tracer tests for post-chlorination actual retention times to determine when 10 percent trace accumulation occurs. If these results show that available retention time is the limiting factor in providing adequate disinfection, then the following options should be considered:

1. Modifying the effluent clearwell by implementation of baffles to create a plug flow situation and minimize mixing and short-circuiting.

2. Increasing the hydraulic retention time by building a baffled chlorine contact chamber of sufficient volume. This alternative, although costly, is probably the only feasible solution to achieve adequate disinfection at Odessa WTP.

E.4.d Process Control

In Section D.5, it was noted that the historical data often showed that measured total chlorine residuals in the treated water were higher than the calculated post-chlorine dosages. This is most likely a measurement or calculation error. Because of the configuration of the chlorinator system, it is difficult to accurately determine the flow split to the pre- and post-chlorine application points, which is a contributing factor to this error. In addition, pre-chlorine dosages should be calculated using actual raw water flow, whereas post-chlorine dosages should be calculated with treated water flows. This has not been the practice in the past.

In order to maintain greater control of the chlorine feed system, it is recommended that each chlorinator be dedicated to one application (i.e. either pre- or post-). In this way, dosage rate adjustment will be more controlled and dosage calculation more accurate. If maintenance or repair of a chlorinator is required, the system can be temporarily changed to the present configuration.

The process control parameters to be used for disinfection are free and total chlorine residuals. Both of these parameters should be measured in grab samples of filtered and treated water and recorded daily. Dosage rates can be adjusted based on these results. In addition, because the plant operates automatically and is often not manned, the treated water free chlorine residual analyzer should be alarmed at a low level of 0.2 mg/L.

E.4.e Total Trihalomethanes

Total trihalomethanes (THMs) are formed in water by the reaction of chlorine with humic organic substances in raw water. The existing MOE Objective maximum level of total THMs in drinking water is 350 mg/L. The 1988 DWSP data in Table I-3 shows

that total THM concentrations in treated water ranged from 5 to 232 mg/L. The available data show that total THM concentrations are well below the MOE objective level. In addition, optimization of the turbidity removal processes in the plant could potentially reduce these levels further.

In order to further reduce the THM levels, it is recommended that the pre-chlorine dosage rate in raw water be maintained to achieve a target residual concentration of 0.1 mg/L in filtered water. In reducing the free chlorine into the GAC contactor, the free chlorine available to react with the humic substances adsorbed to the contactor to form THMs is limited. An added benefit in reducing the chlorine residual concentration is the reduced opportunity for reaction with adsorbed compounds on the GAC.

If the MOE total THM objective becomes more stringent and more efficient measures are required, a number of alternatives are available to reduce the THM concentration in treated water. These include:

1. The existing and recommended coagulation process control parameter is turbidity. In order to reduce the humic substances, the coagulation process can be optimized for TOC removal. In this case, TOC would require monitoring on a routine basis for process control.

2. The GAC filter could be operated for TOC removal. It has been shown that the ability of GAC media to remove THM precursors is much shorter than the exhaustion time for taste and odour removal, and can be as short as 3 to 4 months. Therefore, this alternative could be costly.

E.4.f Summary of Recommendations

Because of the very short retention time in the effluent clearwells at Odessa WTP, it appears that there may be inadequate chlorine contact time for disinfection at low temperature and/or high pH conditions. The following recommendations were made:

- A study should be performed to determine the nominal hydraulic retention time available for pre- or post-chlorination contact.

- If the results indicate insufficient chlorine contact time, then modifications or expansions to the existing clearwell to increase the contact time should be considered.

Other recommendations made to optimize the disinfection process include:

- Dedicating each chlorinator to one application (pre- or post-) to maintain better control of the chlorine dosage rates.

- Measurement of both free and total chlorine in daily grab samples of filtered water and treated water, and dosage adjustment to maintain target ranges as required.

- Maintenance of target free chlorine residual of 0.1 mg/L in filtered water to limit the formation of THMs in the GAC contactor.

- Connecting an alarm in a low free chlorine level of 0.2 mg/L in treated water.

E.5 RAW WATER

Historically, the Odessa WTP has had problems with the raw water source. In winter months, the creek freezes over, causing the raw water to become anoxic or anaerobic. Potential problems associated with these conditions are the absence of dissolved oxygen, the presence of hydrogen sulphide, and elevated iron and manganese levels.

Sulphides present in water supplies result from the anaerobic bacterial action on organic sulphur and sulphites. Threshold odour of hydrogen sulphide occurs at concentrations of less than 100 mg/L. In addition, anaerobic conditions can cause desolubilization of soluble iron and manganese compounds. However, the available 1988 DWSP data does not indicate elevated iron and manganese concentrations.

Also, in the absence of dissolved oxygen in the GAC contactors, there is potential for hydrogen sulphide and other odorous organic compounds to be formed, which are then released. This condition often results if ammonia and limited oxygen is present in GAC influent.

E.5.a Extent of Problem

The duration, intensity and frequency of either anoxic or aerobic raw water conditions have never been documented. It is therefore recommended that a detailed monitoring of the raw water conditions be undertaken to determine the extent of the problem. The monitoring program should include daily measurements of the dissolved oxygen (D.O.) concentrations in the wet well. In addition, when the raw water D.O. level falls below 1 mg/L, hydrogen sulphide (H2S) in the water should be monitored. A HACH kit is available for simple, quick measurements of H_2S concentrations. Finally, DWSP raw water iron and manganese results should be documented in this program.

After each season beginning in the first year of monitoring, the monitoring data should be analyzed by MOE, or a contracted consultant, until the need for control processes has been established.

E.5.b Alternatives to Control Hydrogen Sulphide and D.O. Problems

Once the extent of the problem has been determined, a number of alternatives can be considered for control.

If the water source has a tendency to become anoxic with the D.O. levels dropping to zero, then methods of raising the D.O. in raw water can be considered. Presently, a LIGHTNIN mixer in the raw water wet well runs constantly, to mix the pre-chlorine and to aerate the raw water. This may prove to be insufficient for aeration during anoxic conditions. The following alternatives could be considered:

- Aeration of the raw water source to prevent freezing and to provide oxygen to water near the intake. This may not be possible due to the location of the intake.

- Aeration in raw water wet well.

H_2S may be found to be a problem in winter months when the creek freezes over. In summer, oxygen depletion and H_2S production may also be a problem due to high water temperatures and potential for nitrification. In this situation, aeration of the raw water source may be a viable solution. Aeration would prevent the surface from freezing, thereby preventing the intake water from becoming anaerobic and the formation of sulphides. If this option were to be considered, a detailed evaluation and engineering design based on the creek configuration at the intake and creek flows would be required to determine the size, type and location of aeration devices.

If H_2S is always at low levels, the cost of the above alternative may not be warranted. Typically, odour problems from sulphide bearing water have been treated by either aeration or chlorine oxidation, shown by the following reactions:

$$2S^{2-} + 2O_2 = SO_4^{2-} + S° \text{ (aeration)}$$

$$H_2S + Cl_2 = 2HCl + S° \text{ (chlorine oxidation)}$$

In the case of chlorine oxidation, the reaction is rapid and therefore enough chlorine would be required to meet the natural demand of the water plus the demand of the sulphide plus the desired residual.

Both of the above reactions produce a free sulphur that is colloidal in nature and imparts a milky blue turbidity in water. Waters treated by oxidation may still emit some sulphurous odour even after the colloids have been removed through coagulation, sedimentation and filtration. The GAC contactor may readily remove these odours. However, treatability tests must be undertaken to ensure that the GAC contactor at Odessa can remove this odour.

Selection of a suitable alternative for the raw water quality problems can only be made after the problem has been defined using the described monitoring program results. At this time, the alternatives should be evaluated by MOE, or a contracted consultant, to determine which process will be optimal for the Odessa WTP in terms of effectiveness, simplicity and costs.

E.5.c Summary of Recommendations

The Odessa WTP has typically had poor water quality in winter months due to the development of anoxic or anaerobic conditions when the creek surface freezes over. In order to handle this problem, the following recommendations are made:

- A D.O. and H_2S monitoring program should be established to determine the frequency of anoxic raw water and the frequency, intensity and duration of anaerobic water containing hydrogen sulphide. Iron and manganese concentrations should also be monitored to indicate anaerobic conditions.

Once the extent of the problem has been determined, the following treatment options may be considered:

- Aeration of raw water source to prevent anoxic or anaerobic conditions.
- Oxidation of H_2S with aeration or chlorine addition in the wet well.

E.6 OTHER

E.6.a Flow Monitoring

In order to determine the volume of flow that is wasted daily and plant efficiency, as well as accurately calculating chemical dosage rates, raw water flows must be known. It is therefore recommended that a magmeter flow meter with a chart recorder and totalizer be installed on the 254 mm raw water discharge pipe.

E.6.b Routine Monitoring of Plant Operational Data

As previously discussed, much of the historical data was not available for the Odessa WTP. Critical to optimal operation of a water plant is routine monitoring and organized documentation of all parameters listed in Tables D-1 and D-2. In addition, record sheets should be kept in an organized file format for ease of information retrieval.

E.6.c Laboratory

The laboratory at Odessa WTP is inadequate for clean water testing in terms of cleanliness, access to water supply and equipment.

In order to optimize the existing laboratory for testing, the following are required:

- pH meter
- turbidity standards in the 0-3 FTU range

- H_2S kit (e.g. HACH)
- D.O. meter
- continuously flowing raw and treated water sampling taps
- wash-up sink
- jar testing equipment and sufficient glassware for mixing reagents

E.6.d Operating Staff

Because there are many problems inherent in the design of the Odessa WTP, this plant is difficult to operate and therefore requires more attention than expected for a WTP of this size. At present, the operating staff are responsible for two other projects and cannot devote the needed time for optimization of this plant. It is therefore recommended that one experienced water treatment plant operator be dedicated solely to the operation of the Odessa WTP. This person would work onsite for the full 40 hours of the work week. The other operators would continue to work at the plant site on a part-time basis.

For this option to be feasible, it will also be necessary to build an office space for the full-time operator. Space at the plant is limited and therefore a new building addition or heated trailer is required at the very minimum.

F. SUMMARY OF RECOMMENDATIONS

A number of recommendations were outlined in the previous section for optimization of the Odessa WTP performance and operation. Each recommendation comes under one of the following headings:

- Studies
- Equipment or Process Modification or Expenditures
- Operational Changes

It should be noted that the recommendations contained in this report may have been completed at the time of publication. The following subsections present a summary of CH2M HILL's recommendations for each of these categories.

F.1 STUDIES

A number of studies were recommended to gain a better understanding of the effects of the start-stop operation on turbidity removal and the mechanisms of turbidity removal in the various unit processes. It is recommended that each study be designed, performed and interpreted by MOE or a consultant. Recommendations for subsequent action should also be made by MOE or the consultant.

The recommended studies will:

- Determine the effects of low lift pump startup on turbidity removal performance in the reactor clarifier, filters, GAC contactor and on plant treated water quality.

- Determine the sludge blanket behaviour in the clarifier during plant startup, and optimize the desludging operation.

- Determine the turbidity removal profile in the sand filters including the effects of double flows in one filter during backwashing and a clean filter coming back online. Also, the appropriate terminal head loss setting will be established.

- Determine the terminal head loss and backwashing frequency of the GAC contactor for optimal turbidity removal performance.

In addition, further dioxin/furan analysis of the GAC media to be performed by MOE are recommended to help establish the source of dioxin/furan contamination and the associated health risk.

One additional study is recommended to determine the nominal retention time for pre- and post-chlorination, to establish whether it is adequate for continuing disinfection when the plant operates at a higher percentage of capacity than at present.

F.2 EQUIPMENT OR PROCESS MODIFICATIONS OR EXPENDITURES

An extensive process monitoring program was recommended for Odessa WTP. Therefore, the following equipment is required:

- Online turbidimeters with chart recorders on the clarifier effluent stream, each filter effluent stream and the GAC contactor effluent stream. The clarifier turbidimeter should also be connected to an alarm at a high level.
- A low level alarm on the existing online treated water residual chlorine analyzer.
- A portable D.O. meter for measurement of raw water D.O. concentrations.
- Laboratory upgrading equipment and reagents as required for the full range of parameters to be measured at a WTP, including a pH meter and H_2S analytical kit (i.e. HACH).
- A raw water flow meter with totalizer and chart recorder.

Specific to the sand filters, the following modifications are required:

- Removal, thorough cleaning or if necessary, replacement of the existing sand in the filters.
- Repair of the components in the filter that were causing restrictions in the backwash flow.
- Engineering design and installation of an auxiliary surface wash system.

In addition, the study results may indicate that major piping modification or complete replacement of the filters is necessary to obtain the filtered water turbidity levels expected for a well operated WTP.

Furthermore, the study of effects of start-stop operation on turbidity in treated water may indicate that fewer starts will optimize plant performance. Options to achieve fewer starts include minor modifications (i.e. throttling of low lift pump discharges) or more major modifications (i.e. a continuous flow system or provision of additional clearwell storage). Additional clearwell storage may also be required to achieve adequate disinfection.

If there are found to be significant problems associated with lack of oxygen, H_2S, manganese or iron in raw water, modifications to the intake system will be necessary. These may include simply chlorinating the raw water to reduce H_2S. Alternatively, aeration of the intake or the raw water wet well may be required. The results of the D.O. and H_2S monitoring program must be interpreted by MOE or a consultant before the requirements can be established.

F.3 OPERATIONAL CHANGES

The following changes and additions to existing plant operating procedures were recommended:

- Jar testing should be performed quarterly (minimum) to optimize chemical dosages for maximum colour and turbidity removal.
- 5 minute sludge settling tests done on recirculating sludge in the reactor clarifier should be performed daily to control the desludging operation.
- Filter sand should be inspected annually to identify backwashing effectiveness and other media problems.
- Sand filter backwash water should be inspected quarterly to ensure the backwash cycle is of sufficient length.
- Visual inspection of the GAC backwash water should take place during backwashing to determine when sufficient washing has occurred.
- Quarterly threshold odour numbers should be established by a panel of 3 or more to control the odour removal process.
- Each chlorinator at the Odessa WTP should be dedicated to one application (pre- or post-). Dosage adjustment should be performed as necessary based on free and total chlorine residual concentrations in filtered and treated water.
- The target filtered water free chlorine residual concentrations of 0.1 mg/L should be maintained to limit the formation of THMs in the GAC contactor.
- A D.O. and H_2S monitoring and documentation program should be undertaken, first to determine the extent of the raw water quality problems and prior to this, to monitor and control the effectiveness of the treatment methods (if implemented).
- An overall routine monitoring program should be implemented that involves documentation of all performance and operational parameters on a day to day basis.

REFERENCES

1. "Ontario Drinking Water Objectives", Ontario Ministry of the Environment, ISBN 0-7743-8985-0, 1983.

2. "Guidelines for the Design of Water Treatment Plants and Sewage Treatment Plants", Ontario Ministry of the Environment, 1987.

3. "Velocity Gradients and Internal Work in Fluid Motion", Camp. TR, Stein, P.C., 1984. Journal of the Boston Society of Civil Engineers. Volume 30, 4, p. 219-237.

4. "Activated Carbon: An Oxidant Producing Hydroxylated PCBs". Vordrias, E.A., Larson, R.A., Snoeyink, V.L. and C. Chen, A.S. Water Chlorination Chemistry, Environmental Impacts and Health Effects, Volume 5. Lewis Publishers, Inc. 1984.

5. "Effects of Activated Carbon on the Reactions of Free Chlorine with Phenols". Vordrias, E.A., Larson, R.A., Soeyink, V.L. Enviro. Sci. Technol., Volume 19, No. 5, 1985.

6. "Desorption of Organics Formed on Activated Carbon". Vordrias, E.A., Snoeyink, V.L. and Larson, R.A., J. AWWA, February 1986.

7. "Water Solubility of 2,3,7,8-Tetrachlorodibenzo dioxin", Maple, L., Brunch, R., Throop, L. Enviro. Sci. and Technol. Vol. 20, No. 2, 1986.

8. "Standard Methods for the Examination of Water and Wastewater", 16th Edition, APHA, AWWA, WPCP, 1985.

9. "Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources - Draft". U.S. E.P.A., 1987.

Appendix I

PHYSICAL AND CHEMICAL WATER QUALITY PARAMETERS PARTICULATE REMOVAL SUMMARIES FOR ODESSA WATER TREATMENT PLANT

Table I-1
SUMMARY OF PARTICULATE REMOVAL PARAMETERS AT ODESSA WTP

Month	Parameter		1987 Max.	1987 Min.	1987 Avg.	1986 Max.	1986 Min.	1986 Avg.	1985 Max.	1985 Min.	1985 Avg.
Jan	Turbidity (FTU)	R	1.0	.75	.86	1.0	.8	.9	1.8	.90	1.23
		T	.60	.50	.52	.70	.40	.57	.85	.25	.51
	Colour (TCU)	R	15	15	15	10	10	10	10	10	10
		T	8	5	5.1	5	5	5	5	5	5
	Prime Coagulant (mg/L) Alum										
	Coagulant Aid										
	(1) Aquafloc (mg/L)										
	(2) Clay (mg/L)										
	(3) (mg/L)										
	(4) (mg/L)										
	Metal Res. Al/Fe (mg/L)	R									
		T									
	pH	R	7.9	7.8	7.85	-	-	-	-	-	-
		T	7.9	7.9	7.90	-	-	-	-	-	-
	Temperature (°C)	R	3	2	2.6	2	2	2	3	2	2.14
Feb	Turbidity (FTU)	R	1.0	.60	.79	1.0	.75	.84	2.0	.5	.83
		T	1.1	.40	.49	.6	.35	.42	1.1	.30	.40
	Colour (TCU)	R	22	10	14.9	10	10	10	15	10	10
		T	14	5	5.8	5	5	5	5	5	5
	Prime Coagulant (mg/L) Alum										
	Coagulant Aid										
	(1) Aquafloc (mg/L)										
	(2) Clay (mg/L)										
	(3) (mg/L)										
	(4) (mg/L)										
	Metal Res. Al/Fe (mg/L)	R									
		T									
	pH	R	8.3	7.5	7.9	-	-	-	-	-	-
		T	8.3	7.6	7.9	-	-	-	-	-	-
	Temperature (°C)	R	3	2	2.25	2	2	2	3	2	2.2

Note: Where no data is printed, data is not available.

R = Raw; T = Treated

(23810)/281

Table I-1
(Continued)

Month	Parameter		1987 Max.	1987 Min.	1987 Avg.	1986 Max.	1986 Min.	1986 Avg.	1985 Max.	1985 Min.	1985 Avg.
Mar	Turbidity (FTU)	R	1.0	.60	.78	1.0	.75	.87	2.1	.70	1.24
		T	.60	.40	.48	.5	.40	.43	1.0	.40	.66
	Colour (TCU)	R	15	10	12.2	10	10	10	10	10	10
		T	<5	<5	<5	5	5	5	5	5	5
	Prime Coagulant (mg/L) Alum		23.4	17.8	20.8						
	Coagulant Aid										
	(1) Aquafloc (mg/L)		.41	.32	.37						
	(2) Clay (mg/L)				-						
	(3) (mg/L)										
	(4) (mg/L)										
	Metal Res. Al/Fe (mg/L)	R									
		T									
	pH	R	-	-	7.8	-	-	-	-	-	-
		T	-	-	7.8	-	-	-	-	-	-
	Temperature (°C)	R	10	2	3.8	4	3	3.15	5	3	3.9
Apr	Turbidity (FTU)	R	1.0	.7	.8	1.1	.9	1.0	1.2	.80	.98
		T	.8	.15	.5	.8	.4	.59	.60	.30	.42
	Colour (TCU)	R	24	5	11.6	10	10	10	10	10	10
		T	9	<5	5.1	5	5	5	5	5	5
	Prime Coagulant (mg/L) Alum		70.5	23.2	47.9				19.3	15.9	16.57
	Coagulant Aid										
	(1) Aquafloc (mg/L)		.28	.16	0.2						
	(2) Clay (mg/L)				-						
	(3) (mg/L)										
	(4) (mg/L)										
	Metal Res. Al/Fe (mg/L)	R									
		T									
	pH	R	8.02	7.6	7.9	-	-	8.1	-	-	-
		T	8.09	7.32	7.8	-	-	8.1	-	-	-
	Temperature (°C)	R	20	6	12.8	14	5	7.8	14	4	8.5

Note: Where no data is printed, data is not available.

R = Raw; T = Treated

Table I-1
(Continued)

Month	Parameter		1987 Max.	1987 Min.	1987 Avg.	1986 Max.	1986 Min.	1986 Avg.	1985 Max.	1985 Min.	1985 Avg.
May	Turbidity (FTU)	R	.9	.4	.8	1.5	1.0	1.31	1.5	1.0	1.25
		T	.9	.5	.7	.90	.60	.82	1.0	.45	.77
	Colour (TCU)	R	20	10	14.4	10	10	10	10	10	10
		T	<5	<5	<5	5	5	5	5	5	5
	Prime Coagulant (mg/L) Alum		73.8	20.2	46.89						
	Coagulant Aid										
	(1) Aquafloc (mg/L)		.51	.31	.33						
	(2) Clay (mg/L)				-						
	(3) (mg/L)										
	(4) (mg/L)										
	Metal Res. Al/Fe (mg/L)	R									
		T									
	pH	R	-	-	8.1	-	-	7.5	-	-	-
		T	-	-	7.66	-	-	7.8	-	-	-
	Temperature (°C)	R	20	12	16.1	22	14	15.7	20	14	16.9
Jun	Turbidity (FTU)	R	1.0	.55	.78	1.5	1.0	1.08	1.5	1.2	1.4
		T	.80	.40	.59	.90	.60	.67	1.2	.8	1.0
	Colour (TCU)	R	15	5	9.12	10	10	10	15	10	14.5
		T	5	<5	5	5	5	5	5	5	5
	Prime Coagulant (mg/L) Alum		81.4	23.2	49.4						
	Coagulant Aid										
	(1) Aquafloc (mg/L)		.54	.20	.40						
	(2) Clay (mg/L)		1.3	.46	.90						
	(3) (mg/L)										
	(4) (mg/L)										
	Metal Res. Al/Fe (mg/L)	R									
		T									
	pH	R	8.52	7.56	7.93	-	-	7.8	-	-	-
		T	7.88	7.55	7.79	-	-	7.7	-	-	-
	Temperature (°C)	R	20	17	18.44	22	20	22	22	19	20.4

Note: Where no data is printed, data is not available.

R = Raw; T = Treated

Table I-1
(Continued)

Month	Parameter		1987 Max.	1987 Min.	1987 Avg.	1986 Max.	1986 Min.	1986 Avg.	1985 Max.	1985 Min.	1985 Avg.
Jul	Turbidity (FTU)	R	.95	.40	.75	1.1	.70	.96	2.5	.85	1.4
		T	.60	.35	.47	.80	.50	.64	.95	.60	.79
	Colour (TCU)	R	15	10	13.75	10	10	10	15	15	15
		T	5	<5	5	5	5	5	5	5	5
	Prime Coagulant (mg/L) Alum		72.84	12.4	37.9						
	Coagulant Aid										
	(1) Aquafloc (mg/L)		.45	.35	.40						
	(2) Clay (mg/L)		1.5	1.2	1.3						
	(3) (mg/L)										
	(4) (mg/L)										
	Metal Res. Al/Fe (mg/L)	R									
		T									
	pH	R	7.8	7.7	7.8	-	-	7.6	-	-	-
		T	7.6	7.5	7.5	-	-	7.8			
	Temperature (°C)	R	25	19	21.8	25	22	24.0	24	22	23.7
Aug	Turbidity (FTU)	R	.90	.40	.70	-	-	-	1.4	.65	.91
		T	.50	.35	.43	-	-	-	1.0	.60	.76
	Colour (TCU)	R	15	5	9.25	10	10	10	15	10	14.5
		T	5	<5	<5	5	5	5	5	5	5
	Prime Coagulant (mg/L) Alum		48.6	12.1	29.7	41.4	26.5	34.9			
	Coagulant Aid										
	(1) Aquafloc (mg/L)		.32	.32	.32						
	(2) Clay (mg/L)		4.2	4.2	4.2						
	(3) (mg/L)										
	(4) (mg/L)										
	Metal Res. Al/Fe (mg/L)	R									
		T									
	pH	R	7.8	7.8	7.8	-	-	7.9	-	-	-
		T	7.6	7.6	7.6	-	-	7.7	-	-	-
	Temperature (°C)	R	24	18	20.9	24	20	22.2	25	20	22.6

Note: Where no data is printed, data is not available.

R = Raw; T = Treated

Table I-1
(Continued)

Month	Parameter		1987 Max.	1987 Min.	1987 Avg.	1986 Max.	1986 Min.	1986 Avg.	1985 Max.	1985 Min.	1985 Avg.
Sep	Turbidity (FTU)	R	1.25	.5	.82	1.0	.70	.85	1.1	.70	.87
		T	.90	.35	.47	.80	.48	.59	.80	.50	.60
	Colour (TCU)	R	15	5	9.1	15	10	11.0	15	10	14.25
		T	<5	<5	<5	5	5	5	5	5	5
	Prime Coagulant (mg/L) Alum		48.6	24.3	32.4	39.0	26.7	33.4			
	Coagulant Aid										
	(1) Aquafloc (mg/L)		.36	.36	.36						
	(2) Clay (mg/L)		5.5	5.5	5.5						
	(3) (mg/L)										
	(4) (mg/L)										
	Metal Res. Al/Fe (mg/L)	R									
		T									
	pH	R	8.12	8.0	8.1	8.1	8.0	8.1	-	-	7.4
		T	8.0	7.85	7.9	7.8	7.5	7.65	-	-	7.7
	Temperature (°C)	R	20	16	17.8	20	17	18.4	21	13	16.85
Oct	Turbidity (FTU)	R	1.0	.59	.82	1.0	.60	.79	.90	.75	.84
		T	.8	.3	.51	.70	.40	.52	.80	.50	.64
	Colour (TCU)	R	15	5	11.67	26	10	13.95	15	10	11.59
		T	5	<5	5	11	5	5	5	5	5
	Prime Coagulant (mg/L) Alum		85.0	5.9	21.6						
	Coagulant Aid										
	(1) Aquafloc (mg/L)		*	*	0.14						
	(2) Clay (mg/L)				-						
	(3) (mg/L)										
	(4) (mg/L)										
	Metal Res. Al/Fe (mg/L)	R									
		T									
	pH	R	8.3	8.2	8.3	8.0	7.8	7.9	-	-	-
		T	8.2	8.1	8.2	7.9	7.7	7.8	-	-	-
	Temperature (°C)	R	16	10	13.15	18	10	13.4	13	11	12.4

Note: Where no data is printed, data is not available.

R = Raw; T = Treated

Table I-1
(Continued)

onth	Parameter		1987 Max.	1987 Min.	1987 Avg.	1986 Max.	1986 Min.	1986 Avg.	1985 Max.	1985 Min.	1985 Avg.
ov	Turbidity (FTU)	R	1.5	.5	.82	.90	.70	.82	.90	.70	.84
		T	.9	.3	.61	.70	.40	.52	.80	.45	.58
	Colour (TCU)	R	20	10	14.25	15	15	15	10	10	10
		T	5	<5	5	5	5	5	5	5	5
	Prime Coagulant (mg/L) Alum		93.7	20.2	49.16						
	Coagulant Aid										
	(1) Aquafloc (mg/L)		*	*	0.22						
	(2) Clay (mg/L)				-						
	(3) (mg/L)										
	(4) (mg/L)										
	Metal Res. Al/Fe (mg/L)	R									
		T									
	pH	R	-	-	8.2	8.2	7.9	8.1	-	-	-
		T	-	-	7.9	8.1	7.9	8.0	-	-	-
	Temperature (°C)	R	12	7	9.7	10	5	6.42	11	3	6.3
ec	Turbidity (FTU)	R	1.0	.55	.78	.95	.60	.81	.90	.60	.81
		T	.70	.30	.41	.70	.50	.57	.70	.40	.50
	Colour (TCU)	R	20	5	10.53	15	10	13.8	10	10	10
		T	5	<5	5	5	5	5	5	5	5
	Prime Coagulant (mg/L) Alum		81.7	26.4	47.03						
	Coagulant Aid										
	(1) Aquafloc (mg/L)		1.18	0.69	0.83						
	(2) Clay (mg/L)		6.6	5.1	6.1						
	(3) (mg/L)										
	(4) (mg/L)										
	Metal Res. Al/Fe (mg/L)	R									
		T									
	pH	R	8.3	8.0	8.15	-	-	7.9	-	-	7.9
		T	8.2	7.8	8.0	-	-	8.0	-	-	8.1
	Temperature (°C)	R	9	2	5.85	6	3	4.28	3	2	2.15

ote: Where no data is printed, data is not available.

R = Raw; T = Treated

Table I-2
PARTICULATE REMOVAL PROFILE AT ODESSA WTP

Date	Turbidity (FTU)				Colour (TCU)		Alum Coagulant	Aquafloc Coag. Aid	Clay	Metal Res. Al/Fe (mg/L)		pH		Raw Temp.
	Raw	Set.	Filter	Treat.	Raw	Treat.	mg/L	mg/L	mg/L	Raw	Treat	Raw	Treat.	°C
Jan/87														
1														
2	.85			.60	15	5								3
3														
4	1.0													
5	.85			.50	15	5								3
6	.85			.60	15	8						7.9	7.9	3
7	.85			.50	15	5								3
8	.85			.50	15	5								3
9	.90			.60	15	5								3
10														
11														
12	.85			.50	15	5								3
13	.80			.60	15	5								3
14	.85			.60	15	5								3
15	.85			.60	15	5								3
16	.85			.50	15	5								3
17														
18														
19	.80			.50	15	5								3
20	.75			.50	15	5						7.8	7.9	2
21	.90			.60	15	5								2
22	.85			.60	15	5								2
23														
24														
25														
26				.50	15	5								2
27				.55	15	5								2
28				.50	15	5								2
29				.50	15	5								2
30				.50	15	5								2

Note: Where no data is printed, data is unavailable.

(23810)/272

Table I-2
Continued

ate	Turbidity (FTU)				Colour (TCU)		Alum Coagulant mg/L	Aquafloc Coag. Aid mg/L	Clay mg/L	Metal Res. Al/Fe (mg/L)		pH		Raw Temp. °C
	Raw	Set.	Filter	Treat.	Raw	Treat.				Raw	Treat	Raw	Treat.	
r/87														
1														
2	.65			.50	15									
3	.90			.60										4
4	.70			.60										4
5	.90			.60										3
6	.70			.50										3
7														3
8														
9	.65			.40	15									
	.65			.40	15									2
	.65			.40	15									2
	.70			.50	15									2
	.70			.50	15									2
														2
	.70			.40	15									
					10									2
					10	<5	21.5	.38						3
					10	<5	21.8	.39						3
					10	<5	19.9	.35						3
							19.9	.35						3
							19.9	.35						
					10	<5	20.8	.37						
					10	<5	22.6	.40						3
					10	<5	17.8	.32						3
	.60				10	<5	21.2	.38				7.8	7.8	3
				.40	10	<5	20.8	.37						5
							20.8	.37						9
	1.0						20.8	.37						
	.70			.50	10	<5	20.3	.36						
				.40	15	<5	23.4	.41						10
														9

Where no data is printed, data is unavailable.

0)/272

Table I-2
Continued

te	Turbidity (FTU)				Colour (TCU)		Alum Coagulant	Aquafloc Coag. Aid		Clay	Metal Res. Al/Fe (mg/L)		pH		Raw Temp.
	Raw	Set.	Filter	Treat.	Raw	Treat.	mg/L	mg/L		mg/L	Raw	Treat	Raw	Treat.	°C
1/87															
1						33.6	33.6	1.2							
2	.75			.45	15	<5	42.1	.45	1.5						19
3	.80			.50	10	<5	27.6	.45	1.5						19
4							27.6	.45	1.5						
5							54.4	.44	1.4						
6	.75			.50	15	<5	33.6	.36	1.2						20
7	.80			.50	15	<5	56.0	.40	1.3						19
8	.95			.45	15	<5	44.7	.36	1.2				7.8	7.5	21
9	.85			.35	10	<5	36.1	.37	1.2						20
10	.80			.50	15	<5		.37	1.2						20
11								.37	1.2						
12								.37	1.2						
13								.36	1.2						
14	.40			.45	10	<5	22.5	.44	1.4						22
15	.65			.50	15	<5		.43	1.4						21
16	.90			.50	15	<5	43.8	.35	1.2						21
17	.75			.40	10	<5	48.6	.39	1.3						22
18							24.3	.39	1.3						
19							24.3	.39	1.3						
20	.75			.50	10	<5	48.6	.39	1.3						22
21	.60			.35	15	<5	72.8	.39	1.3				7.7	7.6	23
22	.75			.50	15	5	48.6	.39	1.3						21
23	.65			.35	15	5	72.8	.39	1.3						23
24	.50			.35	15	5	36.4	.39	1.3						22
25							36.4	.39	1.3						
26							24.3	.39	1.3						
27	.85			.60	15	<5	36.4	.39	1.3						25
28	.80			.50	15	<5	36.4	.39	1.3						25
29	.85			.60	15	<5	24.3	.39	1.3						24
30	.80			.50	15	<5	24.3	.39	1.3						24
31							12.4	.39	1.3						24

lote: Where no data is printed, data is unavailable.

Table I-2
Continued

te	Turbidity (FTU)				Colour (TCU)		Alum Coagulant	Aquafloc Coag. Aid	Clay	Metal Res. Al/Fe (mg/L)		pH		Raw Temp.
	Raw	Set.	Filter	Treat.	Raw	Treat.	mg/L	mg/L	mg/L	Raw	Treat	Raw	Treat.	°C
t/87														
1	.9			.6	10	<5	24.3							
2	.9			.7	10	<5	12.13	.90	11.3					16
3							12.13							16
4							12.13							
5	.70			.35	5	<5			11.3					
6	.80			.30	10	<5	85.0	.90						16
7	1.0			.35	15	<5	30.4		11.3			8.2	8.1	15
8	.80			.40	15	<5	5.9							16
9	.70			.35	15	<5	21.5	.90	7.2					16
0							21.5							15
							21.5							
							10.7							
	.75			.4	10	<5		.90	11.3					11
	.60			.35	10	<5								11
	.75			.4	15	<5	12.1							12
	.75			.4	10	<5								11
	.80			.65	5	<5	18.2							
	.59			.60	15	5	10.2	.90	11.3					15
	.50				10		10.5							13
	.80			.45	15	5	9.8		11.3					11
	.85			.50	15	5	9.8							11
							9.8							11
							9.8							
	1.0			.80	15	5	40.5	.90	11.3			8.3	8.2	11
	.90			.75	10	<5	21.3							12
	.80			.50	10	<5	14.3	.90						12
	.80			.55	15	<5	30.7							11
	.75			.7	10	<5	28.6							13
							57.2							

: Where no data is printed, data is unavailable.

10)/272

Table I-2
Continued

Date	Turbidity (FTU)				Colour (TCU)		Alum Coagulant	Aquafloc Coag. Aid	Clay	Metal Res. Al/Fe (mg/L)		pH		Raw Temp.
	Raw	Set.	Filter	Treat.	Raw	Treat.	mg/L	mg/L	mg/L	Raw	Treat	Raw	Treat.	°C
Jan/86														
1														
2	.80			.50	10	5								2
3	.80			.40	10	5								2
4														
5														
6	.90			.60	10	5								2
7	.80			.50	10	5								2
8	.80			.50	10	5								2
9	.90			.50	10	5								2
10	.90			.60	10	5								2
11														
12														
13	.90			.60	10	5								2
14	.90			.60	10	5								2
15	.90			.60	10	5								2
16	.80			.60	10	5								2
17	.90			.50	10	5								2
18														
19														
20	.90			.60	10	5								2
21	.90			.60	10	5								2
22	.90			.60	10	5								2
23	1.0			.60	10	5								2
24	1.0			.70	10	5								2
25														
26														
27	1.0			.60	10	5								2
28	1.0			.60	10	5								2
29	1.0			.60	10	5								2
30	1.0			.60	10	5								2
31	1.0			.60	10	5								2

Note: Where no data is printed, data is unavailable.

Table I-2
Continued

ate	Turbidity (FTU)				Colour (TCU)		Alum Coagulant	Aquafloc Coag. Aid	Clay	Metal Res. Al/Fe (mg/L)		pH		Raw Temp.
	Raw	Set.	Filter	Treat.	Raw	Treat.	mg/L	mg/L	mg/L	Raw	Treat	Raw	Treat.	°C
ar/86														
1														
2														
3	.75			.40	10	5								
4	.80			.45	10	5								3
5	.90			.40	10	5								3
6	.80			.40	10	5								3
7	.85			.40	10	5								3
8														3
9														
0	.80			.40	10	5								
1	.90			.45	10	5								3
2	.80			.45	10	5								3
3	.80			.50	10	5								3
4	.75			.40	10	5								3
5														3
6														
7	.90			.40	10	5								
8	.90			.45	10	5								3
9	.90			.45	10	5								3
0	.90			.45	10	5								3
1	.80			.40	10	5								3
2														3
1														
2	1.0			.40	10	5								
3	1.0			.50	10	5								3
4	1.0			.50	10	5								4
	1.0			.50	10	5								4
														4

e: Where no data is printed, data is unavailable.

310)/272

Table I-2
Continued

Date	Turbidity (FTU)				Colour (TCU)		Alum Coagulant mg/L	Aquafloc Coag. Aid mg/L	Clay mg/L	Metal Res. Al/Fe (mg/L)		pH		Raw Temp. °C
	Raw	Set.	Filter	Treat.	Raw	Treat.				Raw	Treat	Raw	Treat.	
Jul/86														
1														
2	1.0			.70	10	5						7.6	7.8	22
3	1.0			.60	10	5								22
4	1.0			.70	10	5								22
5														
6														
7	1.0			.70	10	5								22
8	.9			.60	10	5								22
9	1.0			.70	10	5								22
10	1.1			.70	10	5								22
11	1.1			.80	10	5								22
12														
13														
14	1.0			.70	10	5								22
15	1.0			.55	10	5								22
16	1.0			.50	10	5								22
17	1.1			.60	10	5								22
18	.90			.70	10	5								22
19														
20														
21	1.1			.60	10	5								24
22	1.0			.60	10	5								24
23	1.0			.70	10	5								24
24	1.0			.60	10	5								24
25	1.1			.70	10	5								24
26														
27														
28	.70				10	5								25
29					10	5								25
30					10	5								25
31					10	5								25

Note: Where no data is printed, data is unavailable.
(23810)/272

Table I-2
Continued

Date	Turbidity (FTU)				Colour (TCU)		Alum Coagulant	Aquafloc Coag. Aid	Clay	Metal Res. Al/Fe (mg/L)		pH		Raw Temp.
	Raw	Set.	Filter	Treat.	Raw	Treat.	mg/L	mg/L	mg/L	Raw	Treat	Raw	Treat.	°C
Oct/86														
1	1.0			.70	10	5								
2	.80			.65	10	5								18
3	.80			.65	10	5								18
4	.75			.50	10	5								18
5														18
6	.80			.45	15	5								
7	.80			.65	15	5								16
8	.85			.50	15	5						7.8	7.7	16
9														16
10	.60			.50	15	5								
11														13
12														
13	.80			.50	26	11								
14	.75			.50	15	5								13
15	.75			.50	15	5						7.9	7.8	13
16	.75			.50	15	5								13
17	.80			.50	15	5								13
18														
19														
20	.80			.60	15	5								13
21	.85			.60	15	5						7.9	7.8	11
22	.80			.50	15	5								11
23	.85			.60	15	5								11
24	.85			.55	15	5								11
25														
26														
27	.70			.42	10	5								11
28	.70			.40	10	5						8.0	7.9	11
29	.80			.50	10	5								11
30	.80			.50	15	5								10
31	.80			.40	15	5								10

Note: Where no data is printed, data is unavailable.

Table I-2
Continued

Date	Turbidity (FTU)				Colour (TCU)		Alum Coagulant	Aquafloc Coag. Aid	Clay	Metal Res. Al/Fe (mg/L)		pH		Raw Temp.
	Raw	Set.	Filter	Treat.	Raw	Treat.	mg/L	mg/L	mg/L	Raw	Treat	Raw	Treat.	°C
Jan/85														
1														
2	1.5			.60	10	5								3
3	1.5			.85	10	5								3
4	1.5			.60	10	5								3
5														
6														
7	1.8			.60	10	5								2
8	1.6			.50	10	5								2
9	1.4			.60	10	5								2
10	1.5			.60	10	5								2
11	1.6			.45	10	5								2
12														
13														
14	1.5			.40	10	5								2
15	1.5			.35	10	5								2
16	1.1			.50	10	5								2
17	.90			.55	10	5								2
18	.90			.55	10	5								2
19														
20														
21	.95			.50	10	5								2
22	1.0			.50	10	5								2
23	.90			.45	10	5								2
24	.90			.45	10	5								2
25	1.0			.50	10	5								2
26														
27														
28	1.0			.45	10	5								2
29	1.0			.55	10	5								2
30	1.0			.25	10	5								2
31	.90			.40	10	5								2

Note: Where no data is printed, data is unavailable.

Table I-2
Continued

Date	Turbidity (FTU)				Colour (TCU)		Alum Coagulant	Aquafloc Coag. Aid	Clay	Metal Res. Al/Fe (mg/L)		pH		Raw Temp.
	Raw	Set.	Filter	Treat.	Raw	Treat.	mg/L	mg/L	mg/L	Raw	Treat	Raw	Treat.	°C
Mar/85														
1	2.0			1.0	10	5								
2														3
3														
4	2.0			1.0	10	5								
5	2.1				10									3
6	1.4				10									3
7	1.4			.60	10	5								4
8	1.1			.60	10	5								5
9				.50		5								4
10				.55		5								
11	1.0			.50	10	5								
12	1.2			.65	10	5								4
13	1.0			.60	10	5								4
14	1.2			1.0	10	5								4
15	1.6			.90	10	5								4
16														4
17														
18	1.4			1.0	10	5								
19	1.4			.90	10	5								4
20	1.2			.60	10	5								4
21	1.0			.60	10	5								4
22	1.0			.50	10	5								4
23														4
24														
25	.70			.60	10	5								
26	.80			.60	10	5								4
27	1.0			.40	10	5								4
28	.90			.40	10	5								4
29	.80			.40	10	5								4
30														4
31														

Note: Where no data is printed, data is unavailable.

Table I-2
Continued

Date	Turbidity (FTU)				Colour (TCU)		Alum Coagulant mg/L	Aquafloc Coag. Aid mg/L	Clay mg/L	Metal Res. Al/Fe (mg/L)		pH		Raw Temp. °C
	Raw	Set.	Filter	Treat.	Raw	Treat.				Raw	Treat	Raw	Treat.	
Jul/85														
1														
2	2.5			.8	15	5								22
3					15	5								24
4					15	5								24
5					15	5								24
6														
7														
8					15	5								24
9					15	5								24
10					15	5								24
11					15	5								24
12					15	5								24
13														
14														
15					15	5								24
16					15	5								24
17					15	5								24
18					15	5								24
19					15	5								24
20														
21														
22					15	5								24
23	1.5		.95		15	5								24
24	1.0		.76		15	5								23
25	2.4		.84		15	5								23
26	1.0		.85		15	5								24
27														
28														
29	1.0		.60		15	5								24
30	.85		.74		15	5								24
31	.91		.79		15	5								22

Note: Where no data is printed, data is unavailable.

(23810)/272

Table I-2
Continued

Date	Turbidity (FTU)				Colour (TCU)		Alum Coagulant	Aquafloc Coag. Aid	Clay	Metal Res. Al/Fe (mg/L)		pH		Raw Temp.
	Raw	Set.	Filter	Treat.	Raw	Treat.	mg/L	mg/L	mg/L	Raw	Treat	Raw	Treat.	°C
Oct/85														
1	.85			.60	15	5								13
2	.85			.55	15	5								13
3	.90			.60	15	5								13
4	.90			.60	15	5								13
5														
6														
7	.75			.75	10	5								13
8	.90			.80	10	5								13
9	.80			.70	10	5								13
10	.70			.65	10	5								13
11	.85			.70	10	5								13
12														
13														
14														
15	.90			.70	15	5								13
16	.90			.70	15	5								13
17	.80			.70	15	5								13
18	.80			.70	10	5								13
19														
20														
21	.90			.50	10	5								12
22	.90			.60	10	5								12
23	.90			.60	10	5								12
24	.80			.50	10	5								12
25	.80			.50	10	5								12
26														
27														
28	.90			.65	10	5								11
29	.80			.60	10	5								11
30	.90			.60	10	5								11
31	.80			.80	10	5								11

Note: Where no data is printed, data is unavailable

Table I-3

DRINKING WATER SURVEILLANCE PROGRAM ODESSA WTP 1988

	WATER TREATMENT PLANT		DISTRIBUTION SYSTEM	
	RAW	TREATED		
			STANDING	FREE FLOW
CHEMISTRY (FLD)				
FLD CHLORINE (COMB) (MG/L)		DET'N LIMIT = N/A		GUIDELINE = N/A
FEB	.	1.000	.	1.100
APR	.	.300	.200	.200
	.	.200	.	.200
MAY	.	.400	.	.
	.	.200	.	.
JUN	.	.600	.	.300
JUL	.	.400	.200	.200
AUG	.	.500	.	.
SEP	.	.300	.200	.200
OCT	.	.500	.	.300
NOV	.	.400	.	.
FLD CHLORINE FREE (MG/L)		DET'N LIMIT = N/A		GUIDELINE = N/A
FEB	.	.100	.	.
APR	.	.300	.100	.100
	.	.500	.100	.100
MAY	.	.500	.100	.900
	.	.200	.	.
JUN	.	.400	.100	.100
JUL	.	.700	.100	.100
AUG	.	.700	1.900	1.900
SEP	.	.800	.100	.300
OCT	.	1.000	.100	.100
NOV	.	1.500	.	.
FLD CHLORINE (TOTAL) (MG/L)		DET'N LIMIT = N/A		GUIDELINE = N/A
FEB	.	1.100	.	1.100
APR	.	.600	.300	.300
	.	.700	.100	.300
MAY	.	.900	.100	.900
	.	.400	.	.
JUN	.	1.000	.100	.200
JUL	.	1.100	.300	.300
AUG	.	1.200	1.900	1.900
SEP	.	1.100	.300	.500
OCT	.	1.500	.100	.400
NOV	.	1.900	.	.

*Note * Refer to End of Table for Key to Abbreviations and Codes.

Table I-3

DRINKING WATER SURVEILLANCE PROGRAM ODESSA WTP 1988

	WATER TREATMENT PLANT		DISTRIBUTION SYSTEM	
	RAW	TREATED	STANDING	FREE FLOW
FLD PH (DMSNLESS)			DET'N LIMIT = N/A	GUIDELINE = 6.5-8.5(A4)
FEB	7.300	7.300	.	7.300
APR	7.600	7.300	.	.
	7.800	7.300	7.600	7.400
MAY	7.500	7.100	7.200	7.000
	7.500	7.100	.	.
JUN	7.500	7.500	7.600	7.600
JUL	7.800	7.500	7.600	7.600
AUG	8.100	7.300	7.400	7.200
SEP	8.200	7.500	7.600	7.600
OCT	7.400	7.000	7.400	7.200
NOV	7.500	7.100	.	.
FLD TEMPERATURE (DEG.C)			DET'N LIMIT = N/A	GUIDELINE = 15 (A1)
FEB	1.000	1.500	.	2.000
APR	8.500	8.000	14.000	6.000
	8.000	9.000	11.000	7.000
MAY	21.000	21.000	18.000	14.000
	15.000	17.500	.	.
JUN	19.000	20.000	19.000	18.000
JUL	20.000	24.000	22.000	21.000
AUG	21.000	21.000	20.000	20.000
SEP	18.000	18.000	20.000	12.000
OCT	9.500	9.000	17.000	12.000
NOV	.600	.700	.	.
FLD TURBIDITY (FTU)			DET'N LIMIT = N/A	GUIDELINE = 1.0 (A1)
FEB	.650	.950	.	.
APR	.700	.900	.	.
	1.200	.580	.	.
MAY	1.500	.730	.	.
	2.100	.720	.	.
JUN	.850	.700	.	.
JUL	1.100	.650	.	.
AUG	.920	.670	.	.
SEP	.900	.600	.	.
OCT	1.200	1.000	.	.
NOV	.400	.300	.	.

Table I-3

DRINKING WATER SURVEILLANCE PROGRAM ODESSA WTP 1988

	WATER TREATMENT PLANT		DISTRIBUTION SYSTEM	
	RAW	TREATED	STANDING	FREE FLOW
CHEMISTRY (LAB)				
ALKALINITY (MG/L)		DET'N LIMIT = .200		GUIDELINE = 30-500 (A4)
FEB	172.000	167.700	.	167.000
APR	129.400	114.900	115.700	114.600
	151.600	149.700	!!S	139.400
MAY	133.900	101.500	100.700	114.700
	155.100	134.400	.	.
JUN	103.900	95.400	91.100	92.300
JUL	113.600	106.600	99.600	98.000
AUG	100.800	82.600	70.200	71.500
SEP	99.700	93.400	88.800	87.500
OCT	119.800	100.000	110.800	110.100
CALCIUM (MG/L)		DET'N LIMIT = .100		GUIDELINE = 100 (F2)
FEB	57.400	56.600	.	57.000
APR	44.800	46.800	47.200	47.400
	47.800	47.200	49.400	50.000
MAY	41.000	40.400	40.800	43.600
	48.000	50.800	.	.
JUN	28.000	27.800	25.800	27.200
JUL	32.800	33.200	31.800	31.800
AUG	27.800	30.200	27.600	27.000
SEP	27.800	27.800	26.800	26.200
OCT	60.200	56.200	55.600	55.600
CYANIDE (MG/L)		DET'N LIMIT = 0.001		GUIDELINE = .200 (A1)
FEB	BDL	BDL	.	BDL
APR	BDL	BDL	.	BDL
	BDL	BDL	.	BDL
MAY	BDL	BDL	.	BDL
	BDL	BDL	.	.
JUN	BDL	.003 <T	.	BDL
JUL	BDL	BDL	.	BDL
AUG	BDL	BDL	.	BDL
SEP	.001	.001	.	BDL
OCT	BDL	BDL	.	BDL

DRINKING WATER SURVEILLANCE PROGRAM ODESSA WTP 1988

	WATER TREATMENT PLANT		DISTRIBUTION SYSTEM	
	RAW	TREATED	STANDING	FREE FLOW
CHLORIDE (MG/L)			DET'N LIMIT = .200	GUIDELINE = 250 (A3)
FEB	17.400	18.700	.	18.800
APR	9.300	11.800	13.100	12.100
	11.200	14.600	14.700	14.300
MAY	12.000	16.000	16.400	16.700
	12.700	17.800	.	.
JUN	13.500	17.700	17.900	18.300
JUL	18.900	23.800	24.200	24.200
AUG	17.500	23.000	27.300	24.900
SEP	18.600	23.800	24.000	23.100
OCT	62.600	62.500	53.400	53.900
COLOUR (TCU)			DET'N LIMIT = .5	GUIDELINE = 5.0 (A3)
FEB	13.500	9.000	.	8.500
APR	15.000	3.500	4.000	!!S
	20.500	10.000	8.000	6.000
MAY	25.500	1.000 <T	.500 <T	1.500 <T
	24.000	1.000 <T	.	.
JUN	27.500	9.000	10.500	8.500
JUL	29.500	8.500	9.500	8.500
AUG	29.000	5.000	3.500	4.000
SEP	18.000	7.500	9.500	8.000
OCT	49.500	16.500	28.000	29.000
CONDUCTIVITY (UMHO/CM)			DET'N LIMIT = 1	GUIDELINE = 400 (F2)
FEB	387	411	.	395
APR	283	299	308	295
	335	351	!!S	371
MAY	303	325	329	342
	337	367	.	.
JUN	258	256	247	253
JUL	300	305	297	292
AUG	272	311	310	302
SEP	274	283	278	275
OCT	561	537	500	508
FLUORIDE (MG/L)			DET'N LIMIT = .01	GUIDELINE = 2.400 (A1)
FEB	.090	.090	.	.090
APR	.060	.050	.050	!!S
	.100	.090	!!S	.060
MAY	.070	.050	.050	.050
	.080	.040 <T	.	.
JUN	.070	.070	.080	.080
JUL	.080	.080	.080	.080
AUG	.100	.080	.060	.060
SEP	.080	.080	.100	.080
OCT	.080	.060	.080	.060

Table I-3

DRINKING WATER SURVEILLANCE PROGRAM ODESSA WTP 1988

	WATER TREATMENT PLANT		DISTRIBUTION SYSTEM	
	RAW	TREATED	STANDING	FREE FLOW
HARDNESS (MG/L)			DET'N LIMIT = .500	GUIDELINE = 80-100 (A4)
FEB	192.000	195.000	.	191.000
APR	142.000	145.000	147.000	148.000
	156.000	155.000	161.000	161.000
MAY	141.000	138.000	140.000	146.000
	156.000	163.000	.	.
JUN	115.000	113.000	105.000	111.000
JUL	130.000	132.000	124.000	126.000
AUG	118.000	128.000	120.000	117.000
SEP	120.000	122.000	118.000	116.000
OCT	199.000	187.000	185.000	188.000
IONCAL (DMSNLESS)			DET'N LIMIT = N/A	GUIDELINE = N/A
FEB	.000 NAF	.000 NAF	.	.000 NAF
APR	.000 NAF	.000 NAF	.000 NAF	.000 NAF
	.000 NAF	.000 NAF	.000 NAF	.000 NAF
MAY	.000 NAF	.000 NAF	.000 NAF	.000 NAF
	.000 NAF	.000 NAF	.	.
JUN	.000 NAF	.000 NAF	.000 NAF	.000 NAF
JUL	.128	1.718	1.240	3.616
AUG	1.851	.158	4.959	5.810
SEP	3.056	3.768	4.115	4.358
OCT	1.370	1.337	1.556	2.900
NOV	.000 NAF	.000 NAF	.	.
LANGELIERS INDEX (DMSNLESS)			DET'N LIMIT = N/A	GUIDELINE = N/A
FEB	.595 NAF	.495 NAF	.	.578 NAF
APR	.561 NAF	.392 NAF	.485 NAF	.508 NAF
	.775 NAF	.773 NAF	.	.745 NAF
MAY	.529 NAF	.039 NAF	.100 NAF	.234 NAF
	.607 NAF	.386 NAF	.	.
JUN	.271 NAF	.262 NAF	.123 NAF	.199 NAF
JUL	.462	.428	.333	.358
AUG	.479	.005	-.245	-.194
SEP	.624	.182	-.004	.021
OCT	.521	.355	.379	.365
NOV	.559 NAF	.072 NAF	.	.

Table I-3

DRINKING WATER SURVEILLANCE PROGRAM ODESSA WTP 1988

	WATER TREATMENT PLANT		DISTRIBUTION SYSTEM	
	RAW	TREATED	STANDING	FREE FLOW
MAGNESIUM (MG/L)			DET'N LIMIT = .050	GUIDELINE = 30 (F2)
FEB	11.900	13.100	.	11.800
APR	7.300	6.900	7.000	7.200
	8.900	9.000	9.000	8.800
MAY	9.300	9.100	9.200	9.100
	8.900	8.800	.	.
JUN	10.900	10.600	10.000	10.500
JUL	11.600	12.000	10.800	11.300
AUG	11.800	12.800	12.400	12.000
SEP	12.400	12.900	12.400	12.200
OCT	11.900	11.400	11.100	11.900
SODIUM (MG/L)			DET'N LIMIT = .200	GUIDELINE = 200 (C3)
FEB	9.600	9.800	.	10.000
APR	5.200	5.600	6.600	5.600
	5.600	5.800	6.000	5.800
MAY	6.400	6.800	7.200	7.000
	6.800	8.000	.	.
JUN	7.800	7.800	7.800	7.800
JUL	9.800	10.000	10.400	10.400
AUG	9.800	9.800	8.800	8.400
SEP	10.400	10.400	10.600	10.600
OCT	37.800	34.400	29.200	30.200
AMMONIUM TOTAL (MG/L)			DET'N LIMIT = 0.002	GUIDELINE = .05 (F2)
FEB	.190	.174	.	.174
APR	.038	.016	.024	IIS
	.048	.008 <T	IIS	.018
MAY	.052	.016	.034	.016
	.200	.078	.	.
JUN	.036	.012	.050	.024
JUL	.064	.024	.152	.034
AUG	.054	.016	.022	.014
SEP	.054	.026	.184	.058
OCT	.026	.010	.040	.064
NITRITE (MG/L)			DET'N LIMIT = 0.001	GUIDELINE = 1.000 (A1)
FEB	.007	.003 <T	.	.002 <T
APR	.060	.002 <T	.002 <T	IIS
	.037	.003 <T	IIS	.002 <T
MAY	.024	.001 <T	.003 <T	.002 <T
	.116	.002 <T	.	.
JUN	.084	.004 <T	.003 <T	.003 <T
JUL	.004 <T	.004 <T	.004 <T	.004 <T
AUG	.003 <T	.003 <T	.003 <T	.003 <T
SEP	.003 <T	.002 <T	.004 <T	.002 <T
OCT	.018	.011	.015	.013

DRINKING WATER SURVEILLANCE PROGRAM ODESSA WTP 1988

	WATER TREATMENT PLANT		- DISTRIBUTION SYSTEM	
	RAW	TREATED		
			STANDING	FREE FLOW
TOTAL NITRATES (MG/L)		**DET'N LIMIT = .020**		**GUIDELINE = 10.000 (A1)**
FEB	.275	.275	.	.265
APR	.100	.080 <T	.075 <T	IIS
	.040 <T	BDL	IIS	BDL
MAY	.045 <T	.035 <T	.040 <T	.035 <T
	.125	.030 <T	.	.
JUN	.235	.025 <T	.050 <T	.030 <T
JUL	.030 <T	.035 <T	.045 <T	.030 <T
AUG	BDL	.025 <T	.045 <T	.030 <T
SEP	.055 <T	.060 <T	.130	.045 <T
OCT	.055 <T	.040 <T	.090 <T	.100
NITROGEN TOT KJELD (MG/L)		**DET'N LIMIT = .020**		**GUIDELINE = N/A**
FEB	.580	.500	.	.580
APR	.420	.280	.290	IIS
	.460	.370	IIS	.360
MAY	.730	.200	.340	.220
	1.020	.200	.	.
JUN	1.000	.670	.820	.800
JUL	1.020	.780	1.040	.830
AUG	1.170	.710	.740	.640
SEP	1.170	1.080	1.410	1.090
OCT	.880	.820	.950	.980
PH (DMSNLESS)		**DET'N LIMIT = N/A**		**GUIDELINE = 6.5-8.5(A4)**
FEB	8.050	7.970	.	8.050
APR	8.230	8.100	8.190	8.210
	8.360	8.370	IIS	8.350
MAY	8.230	7.870	7.930	7.980
	8.180	8.000	.	.
JUN	8.230	8.260	8.170	8.220
JUL	8.330	8.320	8.270	8.300
AUG	8.460	8.050	7.910	7.960
SEP	8.610	8.200	8.050	8.090
OCT	8.130	8.070	8.050	8.040
PHOSPHORUS FIL REACT (MG/L)		**DET'N LIMIT = .0005**		**GUIDELINE = N/A**
FEB	BDL	.000 <T	.	.
APR	.009	.001 <T	.	.
	.008	.001 <T	.	.
MAY	.009	.001 <T	.	.
	.037	.006	.	.
JUN	.018	.001 <T	.	.
JUL	.001 <T	.001 <T	.	.
AUG	.001 <T	.001 <T	.	.
SEP	.001 <T	.001 <T	.	.
OCT	.001 <T	.001 <T	.	.

Table I-3

DRINKING WATER SURVEILLANCE PROGRAM ODESSA L.P 1988

	WATER TREATMENT PLANT		DISTRIBUTION SYSTEM	
	RAW	TREATED	STANDING	FREE FLOW
PHOSPHORUS TOTAL (MG/L)		DET'N LIMIT = .002		GUIDELINE = .40 (F2)
FEB	.019	BDL	.	.
APR	.019	.002 <T	.	.
	.025	.009 <T	.	.
MAY	.033	.008 <T	.	.
	.070	.013	.	.
JUN	.048	.023	.	.
JUL	.016	.017	.	.
AUG	.019	.010	.	.
SEP	.029	.052	.	.
OCT	.020	.017	.	.
SULPHATE ( )		DET'N LIMIT = N/A		GUIDELINE = N/A
JUL	10.500	10.700	10.800	10.700
AUG	10.900	33.150	35.690	34.770
SEP	12.200	12.200	12.400	12.300
OCT	66.680	67.490	55.570	57.650
TURBIDITY (FTU)		DET'N LIMIT = .02		GUIDELINE = 1.00 (A1)
FEB	.920	.700	.	.600
APR	.900	.280	.260	!!S
	1.180	.540	!!S	.270
MAY	1.690	.370	.600	.360
	3.800	.500	.	.
JUN	1.200	.600	.550	.640
JUL	1.200	.760	.520	.850
AUG	.810	.780	.720	.580
SEP	1.020	.840	.910	.570
OCT	1.870	.890	1.440	1.400
METALS				
SILVER (UG/L)		DET'N LIMIT = N/A		GUIDELINE = .05 (A1)
FEB	.030 <T	.020 <T	.	BDL
APR	BDL	BDL	.190 <T	BDL
	BDL	BDL	.030 <T	BDL
MAY	BDL	BDL	.030 <T	BDL
	BDL	.040 <T	.	.
JUN	BDL	BDL	BDL	BDL
JUL	BDL	BDL	.030 <T	BDL
AUG	.080 <T	.050 <T	.060 <T	BDL
SEP	BDL	BDL	BDL	BDL
OCT	.040 <T	.030 <T	.030 <T	BDL

Note: All metal concentrations in the following units (exept where noted)
Results: (µ/L) Det'n Limit: (mg/L) Guideline: (mg/L)

Table I-3

DRINKING WATER SURVEILLANCE PROGRAM ODESSA WTP 1988

	WATER TREATMENT PLANT		DISTRIBUTION SYSTEM	
	RAW	TREATED		
Metals			STANDING	FREE FLOW
ALUMINUM (UG/L)			DET'N LIMIT = .004	GUIDELINE = .10 (A4)
FEB	6.400	380.000	.	360.000
APR	10.000	160.000	110.000	140.000
	8.800	210.000	240.000	250.000
MAY	12.000	340.000	180.000	220.000
	34.000	240.000	.	.
JUN	24.000	97.000	120.000	110.000
JUL	20.000	38.000	39.000	38.000
AUG	11.000	290.000	220.000	230.000
SEP	9.100	25.000	39.000	30.000
OCT	39.000	280.000	74.000	76.000
ARSENIC (UG/L)			DET'N LIMIT = 0.001	GUIDELINE = .050 (A1)
FEB	.320 <T	.340 <T	.	.260 <T
APR	BDL	BDL	BDL	BDL
	BDL	BDL	BDL	BDL
MAY	.460 <T	.430 <T	.490 <T	.460 <T
	.350 <T	2.300	.	.
JUN	.450 <T	.570 <T	.770 <T	.670 <T
JUL	.410 <T	.460 <T	.400 <T	.590 <T
AUG	.760 <T	.650 <T	.730 <T	.670 <T
SEP	.750 <T	.740 <T	.940 <T	1.100
OCT	.540 <T	.490 <T	.530 <T	.550 <T
BARIUM (UG/L)			DET'N LIMIT = 0.001	GUIDELINE = 1.000 (A1)
FEB	56.000	52.000	.	51.000
APR	30.000	31.000	36.000	32.000
	26.000	25.000	30.000	30.000
MAY	37.000	40.000	41.000	41.000
	55.000	62.000	.	.
JUN	39.000	24.000	23.000	26.000
JUL	56.000	45.000	46.000	50.000
AUG	45.000	50.000	54.000	55.000
SEP	43.000	39.000	41.000	39.000
OCT	56.000	90.000	78.000	74.000

Table I-3

DRINKING WATER SURVEILLANCE PROGRAM ODESSA WTP 1988

	WATER TREATMENT PLANT		DISTRIBUTION SYSTEM	
	RAW	TREATED	STANDING	FREE FLOW
BORON (UG/L)		DET'N LIMIT = 0.010		GUIDELINE = 5.000 (A1)
FEB	20.000	21.000	.	18.000 <T
APR	14.000 <T	16.000 <T	17.000 <T	17.000 <T
	16.000 <T	26.000	22.000	19.000 <T
MAY	21.000	15.000 <T	11.000 <T	8.400 <T
	27.000	20.000 <T	.	.
JUN	33.000	27.000	29.000	32.000
JUL	45.000	42.000	55.000	52.000
AUG	42.000	32.000	46.000	45.000
SEP	55.000	37.000	73.000	43.000
OCT	27.000	40.000	35.000	31.000
BERYLLIUM (UG/L)		DET'N LIMIT = 0.001		GUIDELINE = .0002 (H)
FEB	BDL	BDL	.	BDL
APR	.040 <T	BDL	.020 <T	BDL
	.060 <T	.030 <T	.020 <T	.030 <T
MAY	BDL	.050 <T	.030 <T	.060 <T
	BDL	.030 <T	.	.
JUN	BDL	BDL	BDL	BDL
JUL	BDL	BDL	BDL	.030 <T
AUG	BDL	BDL	.030 <T	BDL
SEP	.050 <T	.030 <T	.100 <T	.020 <T
OCT	.050 <T	.020 <T	BDL	.040 <T
CADMIUM (UG/L)		DET'N LIMIT = 0.300		GUIDELINE = 5.000 (A1) (ug/L)
FEB	BDL	BDL	.	BDL
APR	BDL	BDL	BDL	BDL
	BDL	BDL	.200 <T	BDL
MAY	BDL	BDL	BDL	BDL
	BDL	BDL	.	.
JUN	BDL	BDL	BDL	BDL
JUL	BDL	BDL	.220 <T	BDL
AUG	BDL	BDL	.360 <T	BDL
SEP	BDL	BDL	BDL	BDL
OCT	.070 <T	BDL	.400 <T	BDL

Table I-3

DRINKING WATER SURVEILLANCE PROGRAM ODESSA WTP 1988

	WATER TREATMENT PLANT		DISTRIBUTION SYSTEM	
	RAW	TREATED	STANDING	FREE FLOW
COBALT (UG/L)		DET'N LIMIT = 0.001		GUIDELINE = 1.0 (H)
FEB	.020 <T	.040 <T	.	.050 <T
APR	.460 <T	.460 <T	.550 <T	.440 <T
	.100 <T	.090 <T	.100 <T	.060 <T
MAY	.110 <T	.130 <T	.250 <T	.140 <T
	.130 <T	1.400	.	.
JUN	.100 <T	.060 <T	.060 <T	.070 <T
JUL	10.000	.100 <T	.140 <T	.120 <T
AUG	.100 <T	.080 <T	.130 <T	.050 <T
SEP	.120 <T	.120 <T	.170 <T	.140 <T
OCT	.110 <T	.050 <T	.070 <T	.080 <T
CHROMIUM (UG/L)		DET'N LIMIT = 0.001		GUIDELINE = .05 (A1)
FEB	.110 <T	.480 <T	.	.130 <T
APR	.430 <T	.290 <T	.160 <T	.210 <T
	.510 <T	2.000	.770 <T	.470 <T
MAY	.690 <T	1.200	.110 <T	.130 <T
	.710 <T	4.000	.	.
JUN	.480 <T	.450 <T	BDL	.570 <T
JUL	.340 <T	.280 <T	.310 <T	.340 <T
AUG	BDL	BDL	BDL	BDL
SEP	1.600	.870 <T	3.400	.620 <T
OCT	.370 <T	.570 <T	.570 <T	.360 <T
COPPER (UG/L)		DET'N LIMIT = .001		GUIDELINE = 1.0 (A3)
FEB	.360 <T	.370 <T	.	6.200
APR	.340 <T	.420 <T	43.000	5.500
	.360 <T	.410 <T	74.000	5.900
MAY	.540 <T	.250 <T	92.000	9.500
	.570 <T	.660 <T	.	.
JUN	.430 <T	.310 <T	56.000	8.300
JUL	.560 <T	.740 <T	42.000	22.000
AUG	.550 <T	.520 <T	62.000	17.000
SEP	.560 <T	.490 <T	110.000	13.000
OCT	1.300	1.100	190.000	15.000
IRON (UG/L)		DET'N LIMIT = .002		GUIDELINE = .300 (A3)
FEB	65.000	46.000	.	42.000
APR	83.000	17.000 <T	13.000 <T	9.500 <T
	110.000	36.000 <T	24.000 <T	23.000 <T
MAY	100.000	15.000 <T	13.000 <T	26.000 <T
	170.000	25.000 <T	.	.
JUN	51.000	21.000 <T	20.000 <T	20.000 <T
JUL	50.000 <T	19.000 <T	18.000 <T	18.000 <T
AUG	25.000 <T	BDL	5.600 <T	BDL
SEP	13.000 <T	8.300 <T	BDL	5.100 <T
OCT	100.000	46.000 <T	49.000 <T	61.000

Table I-3

DRINKING WATER SURVEILLANCE PROGRAM ODESSA WTP 1988

	WATER TREATMENT PLANT		DISTRIBUTION SYSTEM	
	RAW	TREATED	STANDING	FREE FLOW
LEAD (UG/L)		DET'N LIMIT = 0.003		GUIDELINE = .050 (A1)
FEB	3.200	.170 <T	.	.430
APR	.400	.110 <T	3.200	.640
	3.100	.140 <T	5.800	.610
MAY	1.100	.200 <T	5.600	.920
	.910	.320	.	.
JUN	.860	.300	3.600	1.100
JUL	1.700	.350	8.500	2.900
AUG	.550	.150 <T	8.600	2.300
SEP	.600	.070 <T	14.000	2.000
OCT	.710	.220	24.000	4.500
ANTIMONY (UG/L)		DET'N LIMIT = N/A		GUIDELINE = N/A
FEB	.090 <T	.060 <T	.	.090 <T
APR	.070 <T	.050 <T	.140 <T	.080 <T
	.110 <T	.090 <T	.100 <T	.100 <T
MAY	.060 <T	.030 <T	.080 <T	.040 <T
	.080 <T	.060 <T	.	.
JUN	.080 <T	.050 <T	.110 <T	.090 <T
JUL	20.000	.660	.530	.700
AUG	.430	.440	.460	.420
SEP	.470	.480	.490	.450
OCT	.130 <T	.160 <T	.180 <T	.100 <T
SELENIUM (UG/L)		DET'N LIMIT = 0.001		GUIDELINE = .010 (A1)
FEB	.800 <T	.730 <T	.	.840 <T
APR	BDL	BDL	BDL	BDL
	BDL	.580 <T	.640 <T	.810 <T
MAY	.780 <T	.780 <T	.260 <T	.220 <T
	.740 <T	.790 <T	.	.
JUN	.500 <T	BDL	1.400 <T	2.400 <T
JUL	1.600 <T	1.200 <T	1.700 <T	.340 <T
AUG	BDL	2.600 <T	3.700 <T	1.100 <T
SEP	BDL	.800 <T	3.200 <T	2.500 <T
OCT	.790 <T	1.200 <T	1.500 <T	1.300 <T

DRINKING WATER SURVEILLANCE PROGRAM ODESSA WTP 1988

	WATER TREATMENT PLANT		DISTRIBUTION SYSTEM	
	RAW	TREATED	STANDING	FREE FLOW
MERCURY (UG/L)		DET'N LIMIT = 0.010		GUIDELINE = 1.000 (A1) (µg/L)
FEB	BDL	BDL	.	BDL
APR	BDL	BDL	.	BDL
	.010	BDL	.	BDL
MAY	BDL	BDL	.	BDL
	BDL	BDL	.	.
JUN	.020 <T	BDL	.	BDL
JUL	.020 <T	.020 <T	.	BDL
AUG	.020 <T	.020 <T	.	ISS
SEP	.020 <T	.030 <T	.	BDL
OCT	.040 <T	.030 <T	.	BDL
MANGANESE (UG/L)		DET'N LIMIT = .001		GUIDELINE = .050 (A3)
FEB	31.000	24.000	.	23.000
APR	15.000	9.000	8.200	8.000
	33.000	7.900	12.000	14.000
MAY	29.000	13.000	6.900	9.800
	82.000	57.000	.	.
JUN	14.000	4.800	5.100	4.200
JUL	19.000	2.400	2.300	2.200
AUG	6.300	.880	1.100	.920
SEP	9.200	6.300	6.100	5.800
OCT	50.000	2.700	2.400	2.100
MOLYBDENUM (UG/L)		DET'N LIMIT = 0.001		GUIDELINE = .50 (H)
FEB	.160 <T	.180 <T	.	.180 <T
APR	.150 <T	.140 <T	.200 <T	.180 <T
	.120 <T	.220 <T	.130 <T	.150 <T
MAY	.060 <T	.230 <T	.260 <T	.240 <T
	.120 <T	.280 <T	.	.
JUN	.030 <T	.070 <T	.080 <T	.160 <T
JUL	.030 <T	.070 <T	.080 <T	.080 <T
AUG	.040 <T	BDL	.030 <T	.040 <T
SEP	BDL	BDL	.030 <T	.030 <T
OCT	.260 <T	.230 <T	.200 <T	.180 <T
NICKEL (UG/L)		DET'N LIMIT = 0.001		GUIDELINE = .05 (F3)
FEB	BDL	BDL	.	BDL
APR	1.400 <T	1.500	4.400	1.300 <T
	.490 <T	.220 <T	9.400	.300 <T
MAY	.130 <T	BDL	9.200	.400 <T
	BDL	1.700 <T	.	.
JUN	BDL	BDL	4.600	BDL
JUL	.160 <T	.270 <T	4.800	.290 <T
AUG	BDL	BDL	8.300	BDL
SEP	BDL	BDL	8.200	.110 <T
OCT	.350 <T	.110 <T	3.100	.660 <T

Table I-3

DRINKING WATER SURVEILLANCE PROGRAM ODESSA WTP 1988

	WATER TREATMENT PLANT		DISTRIBUTION SYSTEM	
	RAW	TREATED	STANDING	FREE FLOW
STRONTIUM (UG/L)			**DET'N LIMIT = .001**	**GUIDELINE = 2.00 (H)**
FEB	1200.000	1200.000	.	1200.000
APR	790.000	770.000	810.000	800.000
	1000.000	1000.000	1100.000	1100.000
MAY	990.000	960.000	990.000	990.000
	1000.000	1100.000	.	.
JUN	950.000	930.000	840.000	910.000
JUL	1200.000	1100.000	1100.000	1200.000
AUG	960.000	990.000	1000.000	1000.000
SEP	990.000	1000.000	950.000	960.000
OCT	900.000	1100.000	830.000	870.000
TITANIUM (UG/L)			**DET'N LIMIT = N/A**	**GUIDELINE = N/A**
FEB	9.200	9.300	.	8.800
APR	7.600	6.900	7.300	6.700
	5.400	4.600	5.000	4.100
MAY	5.900	4.200	4.800	4.100
	9.500	6.000	.	.
JUN	10.000	9.500	9.100	8.500
JUL	8.200	6.000	5.900	6.100
AUG	15.000	14.000	14.000	13.000
SEP	14.000	13.000	14.000	14.000
OCT	9.700	7.500	8.100	7.800
THALLIUM (UG/L)			**DET'N LIMIT = N/A**	**GUIDELINE = N/A**
FEB	BDL	BDL	.	BDL
APR	BDL	BDL	BDL	BDL
	BDL	BDL	BDL	BDL
MAY	.050 <T	.040 <T	.040 <T	.030 <T
	BDL	BDL	.	.
JUN	.040 <T	.040 <T	BDL	.030 <T
JUL	BDL	BDL	BDL	BDL
AUG	BDL	BDL	BDL	BDL
SEP	BDL	BDL	BDL	BDL
OCT	BDL	BDL	BDL	BDL
URANIUM (UG/L)			**DET'N LIMIT = .02**	**GUIDELINE = 20. (A2)** (µg/L)
FEB	.130 <T	.190 <T	.	.210
APR	.110 <T	.040 <T	.110 <T	.060 <T
	.170 <T	.160 <T	.130 <T	.100 <T
MAY	.060 <T	BDL	BDL	BDL
	.090 <T	.030 <T	.	.
JUN	BDL	.090 <T	.040 <T	.050 <T
JUL	BDL	.080 <T	BDL	BDL
AUG	.060 <T	.030 <T	BDL	.030 <T
SEP	.080 <T	.070 <T	BDL	.070 <T
OCT	.180 <T	.090 <T	.140 <T	.130 <T

TableI-3

DRINKING WATER SURVEILLANCE PROGRAM ODESSA WTP 1988

	WATER TREATMENT PLANT		DISTRIBUTION SYSTEM	
	RAW	TREATED	STANDING	FREE FLOW
VANADIUM (UG/L)		DET'N LIMIT = .001		GUIDELINE = .10 (H)
FEB	.210 <T	.190 <T	.	.170 <T
APR	.350 <T	.270 <T	.320 <T	.330 <T
	.340 <T	.220 <T	.260 <T	.210 <T
MAY	.430 <T	.280 <T	.230 <T	.220 <T
	.520	.200 <T	.	.
JUN	.490 <T	.830	.940	.940
JUL	.330 <T	.550	.620	.590
AUG	.510	.400 <T	.340 <T	.310 <T
SEP	.680	.590	.650	.680
OCT	.660	.480 <T	.530	.550
ZINC (UG/L)		DET'N LIMIT = .001		GUIDELINE = 5.00 (A3)
FEB	1.800	.690 <T	.	1.800
APR	1.100	.980 <T	12.000	4.800
	1.500	.670 <T	21.000	2.700
MAY	1.500	4.000	33.000	4.500
	2.000	2.400	.	.
JUN	1.400	1.300	8.200	1.500
JUL	2.100	1.200	16.000	4.000
AUG	1.200	3.400	19.000	3.700
SEP	1.300	2.100	27.000	2.800
OCT	7.300	3.600	25.000	5.000

PESTICIDES & PCB

ALPHA BHC (NG/L)		DET'N LIMIT = 1.000		GUIDELINE = 700 (G)
FEB	BDL	BDL	.	BDL
APR	BDL	BDL	.	BDL
	BDL	BDL	.	BDL
MAY	BDL	BDL	.	BDL
	1.000 <T	BDL	.	.
JUN	BDL	BDL	.	BDL
JUL	BDL	BDL	.	ILA
AUG	BDL	BDL	.	BDL
SEP	1.000 <T	BDL	.	BDL
OCT	BDL	BDL	.	BDL

Table I-3

DRINKING WATER SURVEILLANCE PROGRAM ODESSA WTP 1988

	WATER TREATMENT PLANT		DISTRIBUTION SYSTEM	
	RAW	TREATED	STANDING	FREE FLOW
PHENOLICS				
PHENOLICS (UG/L)		DET'N LIMIT = 0.2		GUIDELINE = 2.00 (A3)
FEB	.400 <T	BDL	.	.
APR	BDL	BDL	.	.
	BDL	.200 <T	.	.
MAY	2.400	6.000	.	.
	.200 <T	BDL	.	.
JUN	6.000	4.800	.	.
JUL	3.800	3.000	.	.
AUG	3.200	2.800	.	.
SEP	8.400	7.600	.	.
OCT	8.000	6.000	.	.
VOLATILES				
BENZENE (UG/L)		DET'N LIMIT = .050		GUIDELINE = 5.0 (B1)
APR	BDL	BDL	.	BDL
	BDL	BDL	.	BDL
MAY	BDL	BDL	.	BDL
	BDL	BDL	.	.
JUN	BDL	BDL	.	BDL
JUL	BDL	BDL	.	BDL
AUG	BDL	.100 <T	.	BDL
SEP	BDL	BDL	.	BDL
OCT	BDL	BDL	.	BDL
TOLUENE (UG/L)		DET'N LIMIT = .050		GUIDELINE = 24.0 (B4)
APR	BDL	.050 <T	.	BDL
	BDL	BDL	.	BDL
MAY	BDL	BDL	.	BDL
	BDL	BDL	.	.
JUN	.050 <T	.050 <T	.	.050 <T
JUL	BDL	BDL	.	BDL
AUG	BDL	BDL	.	BDL
SEP	BDL	BDL	.	BDL
OCT	BDL	BDL	.	BDL

Table I-3

DRINKING WATER SURVEILLANCE PROGRAM ODESSA WTP 1988

	WATER TREATMENT PLANT			DISTRIBUTION SYSTEM
	RAW	TREATED		
			STANDING	FREE FLOW
ETHYLBENZENE (UG/L)		DET'N LIMIT = .050		GUIDELINE = 2.4 (B4)
APR	BDL	BDL	.	BDL
	BDL	BDL	.	BDL
MAY	BDL	BDL	.	BDL
	BDL	BDL	.	.
JUN	BDL	.150 <T	.	.050 <T
JUL	.050 <T	BDL	.	.050 <T
AUG	BDL	BDL	.	.100 <T
SEP	.100 <T	.100 <T	.	.100 <T
OCT	BDL	BDL	.	.050 <T
O-XYLENE (UG/L)		DET'N LIMIT = .050		GUIDELINE = 300 (B4)
APR	BDL	.050 <T	.	BDL
	BDL	BDL	.	BDL
MAY	BDL	BDL	.	BDL
	BDL	BDL	.	.
JUN	BDL	BDL	.	BDL
JUL	BDL	BDL	.	BDL
AUG	BDL	.050 <T	.	BDL
SEP	BDL	BDL	.	.050 <T
OCT	BDL	BDL	.	BDL
STYRENE (UG/L)		DET'N LIMIT = N/A		GUIDELINE = N/A
OCT	.100 <T	.200 <T	.	.450 <T
CHLOROFORM (UG/L)		DET'N LIMIT = .100		GUIDELINE = 350 (A1+)
APR	BDL	63.800	.	61.700
	BDL	64.200	.	62.500
MAY	BDL	10.400	.	22.900
	BDL	4.400	.	.
JUN	BDL	102.000	.	82.300
JUL	.300 <T	181.400	.	148.000
AUG	.100 <T	144.000	.	194.000
SEP	BDL	195.000	.	170.000
OCT	2.400	145.000	.	116.000

Table I-3

DRINKING WATER SURVEILLANCE PROGRAM ODESSA WTP 1988

	WATER TREATMENT PLANT		DISTRIBUTION SYSTEM	
	RAW	TREATED	STANDING	FREE FLOW
DICHLOROBROMOMETHANE (UG/L) DET'N LIMIT = .050 GUIDELINE = 350 (A1+)				
APR	BDL	6.700	.	6.700
	BDL	10.900	.	10.600
MAY	BDL	4.200	.	4.650
	BDL	.450 <T	.	.
JUN	BDL	10.100	.	9.850
JUL	BDL	23.400	.	15.200
AUG	BDL	26.100	.	32.650
SEP	BDL	33.400	.	26.300
OCT	.250 <T	18.950	.	15.500
CHLORODIBROMOMETHANE (UG/L) DET'N LIMIT = .100 GUIDELINE = 350 (A1+)				
APR	BDL	1.000	.	.300 <T
	BDL	.200 <T	.	.200 <T
MAY	BDL	2.100	.	1.200
	BDL	.100 <T	.	.
JUN	BDL	1.100	.	1.600
JUL	BDL	2.400	.	1.700
AUG	BDL	2.200	.	3.200
SEP	BDL	3.500	.	3.600
OCT	BDL	.800 <T	.	.600 <T
T-CHLOROETHYLENE (UG/L) DET'N LIMIT = .050 GUIDELINE = 10.0 (C2)				
APR	BDL	BDL	.	BDL
	BDL	BDL	.	BDL
MAY	BDL	BDL	.	BDL
	BDL	BDL	.	.
JUN	BDL	BDL	.	BDL
JUL	BDL	BDL	.	BDL
AUG	BDL	BDL	.	BDL
SEP	BDL	BDL	.	.050 <T
OCT	BDL	BDL	.	BDL
TOTL TRIHALOMETHANES (UG/L) DET'N LIMIT = .500 GUIDELINE = 350 (A1)				
APR	BDL	71.500	.	68.700
	BDL	75.300	.	73.300
MAY	BDL	16.700	.	28.750
	BDL	4.950 <T	.	.
JUN	BDL	113.200	.	93.550
JUL	BDL	207.200	.	164.900
AUG	BDL	172.300	.	229.850
SEP	BDL	231.900	.	199.900
OCT	2.650 <T	164.800	.	132.100

KEY TO D W S P TABLES

A ONTARIO DRINKING WATER OBJECTIVES

1. Maximum Acceptable Concentration (MAC)
1+. MAC for Total Trihalomethanes
1*. MAC for Bacteriological Analyses
Poor water quality is indicated when :
- total coliform counts > 0 < 5
- P/A Bottle Test is present after 48 hours
- Aeromonas organisms are detected in more than 25% of samples in a single submission or in successive submissions from the same sampling site
- Pseudomonas Aeruginosa, Staphylococcus Aureus and members of the Fecal Streptococcus group should not be detected in any sample
- Standard Plate Count should not exceed 500 organisms per ml at 35 ^{0}C within 48 hours
2. Interim Maximum Acceptable Concentration (IMAC)
3. Maximum Desirable Concentration (MDC)
4. Aesthetic or Recommended Operational Guideline
- hardness levels between 80 and 100 mg/L as calcium carbonate are considered to provide an acceptable balance between corrosion and incrustation, water supplies with a hardness >200 mg/L are considered poor and those in excess of 500 mg/L are unacceptable.

B HEALTH & WELFARE CANADA

1. Maximum Acceptable Concentration (MAC)
2. Proposed MAC
3. Interim MAC
4. Aesthetic Objective (AO) (for xylenes, the AO is a total)

C WORLD HEALTH ORGANIZATION

1. Guideline Value (GV)
2. Tentative GV
3. Aesthetic GV

D US ENVIRONMENTAL PROTECTION AGENCY (EPA)

1. Maximum Contaminant Level (MCL)
2. Suggested No-Adverse Effect Level (SNAEL)
3. Lifetime Health Advisory
4. EPA Ambient Water Quality Criteria

F EUROPEAN ECONOMIC COMMUNITY (EEC)

1. Health Related Guideline Level
2. Aesthetic Guideline Level
3. Maximum Admissable Concentration (MADC)

G CALIFORNIA STATE DEPARTMENT OF HEALTH-GUIDELINE VALUE

H USSR MAXIMUM PERMISSIBLE CONCENTRATION

I NEW YORK STATE AMBIENT WATER GUIDELINE

N/A NONE AVAILABLE

LABORATORY RESULTS, REMARK DESCRIPTIONS

.	No Sample Taken
BDL	Below Minimum Measurable Amount
<T	Greater Than Detection Limit But Not Confident
>	Results Are Greater Than The Upper Limit
<=>	Approximate Result
!AW	No Data: Analysis Withdrawn
!CR	No Data: Could Not Confirm By Reanalysis
!CS	No Data: Contamination Suspected
!IL	No Data: Sample Incorrectly Labelled
!IS	No Data: Insufficient Sample
!LA	No Data: Laboratory Accident
!LD	No Data: Test Queued After Sample Discarded
!NA	No Data: No Authorization To Perform Reanalysis
!NP	No Data: No Procedure
!NR	No Data: Sample Not Received
!OP	No Data: Obscured Plate
!PE	No Data: Procedural Error - Sample Discarded
!PH	No Data: Sample pH Outside Valid Range
!RO	No Data: See Attached Report (no numeric results)
!SM	No Data: Sample Missing
!SS	No Data: Send Separate Sample Properly Preserved
!UI	No Data: Indeterminant Interference
A3C	Approximate, Total Count Exceeded 300 Colonies
APL	Additional Peak, Large, Not Priority Pollutant
APS	Additional Peak, Less Than, Not Priority Pollutant
CIC	Possible Contamination, Improper Cap
CRO	Calculated Result Only

PPS	Test Performed On Preserved Sample
RMP	P and M-Xylene Not Separated
RRV	Rerun Verification
RVU	Reported Value Unusual
SPS	Several Peaks, Small, Not Priority Pollutant
UAL	Unreliable: Sample Age Exceeds Normal Limit
UCR	Unreliable: Could Not Confirm By Reanalysis
UCS	Unreliable: Contamination Suspected
UIN	Unreliable: Indeterminant Interference
XP	Positive After X Number of Hours

Appendix II

BACTERIOLOGICAL WATER QUALITY DATA FOR ODESSA WTP

Table II-2

DRINKING WATER SURVEILLANCE PROGRAM ODESSA WTP 1988

	WATER TREATMENT PLANT		DISTRIBUTION SYSTEM	
	RAW	TREATED	STANDING	FREE FLOW
BACTERIOLOGICAL				
AEROMONAS SP (0=ABSENT)			**DET'N LIMIT = N/A**	**GUIDELINE = 0 (A1)**
APR	.	0	.	.
E. COLI P/A (0=ABSENT)			**DET'N LIMIT = N/A**	**GUIDELINE = N/A**
APR	.	0	.	.
FECAL COLIFORM MF (CT/100ML)			**DET'N LIMIT = 0**	**GUIDELINE = 0 (A1)**
FEB	2	.	.	.
APR	1	.	.	.
	1	.	.	.
MAY	19	.	.	.
	14	.	.	.
JUN	3	.	.	.
JUL	4	.	.	.
AUG	BDL	.	.	.
SEP	3 T48	.	.	.
OCT	22 T48	.	.	.
NOV	4 T48	.	.	.
FECAL COLIFORM (0=ABSENT)			**DET'N LIMIT = N/A**	**GUIDELINE = 0 (A1)**
APR	.	0	.	.
STANDRD PLATE CNT MF (CT/ML)			**DET'N LIMIT = 0**	**GUIDELINE = 500/ML (A1)**
FEB	620	13	.	8
APR	780	12	.	TAW
	1300	28	.	1
MAY	860	3	.	2
	2400 >	44	.	.
JUN	2400 >	1200	.	2400 >
JUL	14000	2400 >	.	2400 >
AUG	1600	4	.	1
SEP	.	17 T48	.	24000 >
OCT	.	56 T48	.	490 T24
NOV	.	4 <=>	.	.

NOTE: Refer to Table I-3 for key to Abbreviations and Codes.

Table II-2

DRINKING WATER SURVEILLANCE PROGRAM ODESSA WTP 1988

	WATER TREATMENT PLANT		DISTRIBUTION SYSTEM	
	RAW	TREATED	STANDING	FREE FLOW
P/A BOTTLE (0=ABSENT)		DET'N LIMIT = 0		GUIDELINE = 0 (A1*)
FEB	.	0	.	0
APR	.	0	.	0
	.	1	.	0
MAY	.	0	.	0
	.	0	.	.
JUN	.	0	.	0
JUL	.	0	.	0
AUG	.	0	.	0
STAPH AUREUS (0=ABSENT)		DET'N LIMIT = N/A		GUIDELINE = 0 (A1)
APR	.	0	.	.
COLIFORM (0=ABSENT)		DET'N LIMIT = N/A		GUIDELINE = 0 (A1)
APR	.	1	.	.
TOTAL COLIFORM MF (CT/100ML)		DET'N LIMIT = 0		GUIDELINE = 5/100ML(A1)
FEB	1500	0	.	0
APR	1300	0	.	0
	2100	0	.	0
MAY	42 A3C	0	.	0
	1200	0	.	.
JUN	6 A3C	0	.	0
JUL	100 A3C	0	.	2 A3C
AUG	14	0	.	0
SEP	600 A3C	0 T48	.	0 A3C
OCT	1240 A3C	0 T48	.	0 T24
NOV	900 A3C	0 T48	.	.
T COLIFORM BCKGRD MF (CT/100ML)		DET'N LIMIT = 0		GUIDELINE = N/A
FEB	1600	0	.	0
APR	4100	0	.	0
	16000	0	.	0
MAY	2400	0	.	2
	7600	0	.	.
JUN	4800 >	2400 >	.	33
JUL	12000	0	.	1800
AUG	1400	2	.	0
SEP	40000 A3C	0 T48	.	2400 >
OCT	48000 >	0 T48	.	100 T24
NOV	15000 A3C	2 T48	.	.

Table II-1
BACTERIOLOGICAL TESTING RESULTS FOR ODESSA WTP

Month	R/t	Total Coliform					Fecal Coliform					Fecal Streptococcus			
		Absent	1-5	6-100	101-5000	>5000	Absent	1-5	6-10	11-500	>500	Absent	1	2-50	>50
1987															
Jan	R			3					3						
	T	3													
Feb	R			3					3						
	T	3													
Mar	R			2					2						
	T	2													
Apr	R			4					2	2					
	T	4													
May	R			3					1	2					
	T	3													
Jun	R			1	3				1	3					
	T	4													
Jul	R			1	1				2						
	T	2													
Aug	R			2	1				1	2					
	T	3													
Sep	R			2	1				1						
	T	3													
Oct	R			3	1				2						
	T	4													
Nov	R			3					2	1					
	T	3													
Dec	R			1					1						
	T	1													
1986															
Jan	R			2	1				2						
	T	3													
Feb	R			4					4						
	T	4													
Mar	R			4					4						
	T	4													
Apr	R			3					3						
	T	3													
May	R			2	2				1	3					
	T	4													
Jun	R			1	2				2	2					
	T	4													
Jul	R			3					3						
	T	3													
Aug	R			4					4						
	T	4													
Sep	R			3					2	1					
	T	3													
Oct	R			2	2					4					
	T	4													
Nov	R			4					3	1					
	T	4													
Dec	R			2					2						
	T	2													
1985															
Jan	R			4					3	1					
	T	4													
Feb	R			2					2						
	T	2													
Mar	R			2	1				2	1					
	T	3													
Apr	R			4					4						
	T	5													
May	R			2					4						
	T	3													
Jun	R			2	1				1						
	T	4													
Jul	R			3	1				4	1					
	T	5													
Aug	R			3	1				2	2					
	T	4													
Sep	R			1	2				2	1					
	T	3													
Oct	R			2	1	1			4	1					
	T	5													
Nov	R			2	1				1	2					
	T	3													
Dec	R			3					2	1					
	T	3													

All results are for 100 ml samples.

R = Raw

T = Treated

(23810)/277

Appendix III

SUMMARY OF FLOWS FOR ODESSA WTP

Table III-1
SUMMARY OF FLOWS AT ODESSA WTP

Month	R/T	1987 Max.	1987 Min.	1987 Avg.	1986 Max.	1986 Min.	1986 Avg.	1985 Max.	1985 Min.	1985 Avg.
Jan	R	.693	.433	.580	.888	.687	.790	1.385	1.054	1.230
	T	.693	.433	.580	.888	.687	.790	1.385	1.054	1.230
Feb	R	.663	.413	.60	.885	.527	.780	1.528	.686	1.210
	T	.663	.413	.60	.885	.527	.780	1.528	.686	1.210
Mar	R	.729	.546	.613	.675	.522	.590	1.587	.925	1.17
	T	.729	.546	.610	.675	.522	.590	1.587	.925	1.17
Apr	R	.815	.571	.678	.634	.467	.540	1.265	.941	1.120
	T	.785	.551	.660	.634	.467	.540	1.265	.941	1.120
May	R	1.040	.587	.777	.901	.471	.620	1.689	.784	1.15
	T	.981	.547	.700	.901	.471	.620	1.689	.784	1.15
Jun	R	1.530	.569	.736	.741	.445	.607	1.221	.990	1.08
	T	1.473	.519	.700	.741	.445	.607	1.221	.990	1.08
Jul	R	.831	.649	.749	1.111	.471	.748	1.399	.956	1.264
	T	.796	.619	.740	1.111	.471	.748	1.399	.956	1.264
Aug	R	x	x	.750	.971	.440	.550	1.544	.823	1.140
	T	x	x	.750	.971	.440	.550	1.544	.823	1.140
Sep	R	x	x	.750	.682	.426	.560	1.401	.408	.950
	T	x	x	.750	.682	.426	.560	1.401	.408	.950
Oct	R	2.031	.595	1.457	.654	.417	.560	1.150	.813	1.02
	T	2.031	.595	1.457	.654	.417	.560	1.150	.813	1.02
Nov	R	.896	.425	.548	.655	.435	.570	1.102	.883	.990
	T	.896	.425	.550	.655	.435	.570	1.102	.883	.990
Dec	R	.625	.377	.538	.664	.467	.560	1.152	.492	.690
	T	.615	.357	.520	.664	.467	.560	1.152	.492	.690

R = Raw
T = Treated
x = Tower under repair

Appendix IV

DISINFECTION SUMMARIES FOR ODESSA WTP

Table IV-1
DISINFECTION SUMMARY FOR ODESSA WTP

Month	Chemical	1987						1986						1985					
		Pre-			Post-			Pre-			Post-			Pre-			Post-		
		Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
Jan	Cl_2 Demand Cl_2 Dosage NH_3 SO_2	6.5	2.5	3.48	.80	.31	.44	7.5	3.2	4.98	.92	.39	.60	7.0	3.3	5.2	.94	.41	.66
	Cl_2 Res. (Free) Cl_2 Res. (Comb.) Cl_2 Res. (Total)	1.0	.4	.7	.80	1.0	.4	1.0	.6	.68	.8	.3	.60	1.5	.3	.94	1.0	.5	.69
Feb	Cl_2 Demand Cl_2 Dosage NH_3 SO_2	5.5	2.5	4.3	.67	.41	.53	4.9	2.7	3.7	.60	.35	.45	12.39	4.4	6.75	1.53	.54	.83
	Cl_2 Res. (Free) Cl_2 Res. (Comb.) Cl_2 Res. (Total)	1.0	.4	.73	1.0	.5	.66	1.0	.3	.76	1.0	.6	.68	1.0	.3	.73	1.0	.3	.68
Mar	Cl_2 Demand Cl_2 Dosage NH_3 SO_2	7.3	2.3	3.4	0.9	.31	.42	7.3	3.0	4.66	.9	.37	.57	9.18	2.64	4.85	1.1	.32	.59
	Cl_2 Res. (Free) Cl_2 Res. (Comb.) Cl_2 Res. (Total)	1.0	.2	.67	1.0	.4	.61	1.0	.5	.81	.8	.4	.61	1.0	.7	.95	1.0	.4	.62
Apr	Cl_2 Demand Cl_2 Dosage NH_3 SO_2	6.0	2.1	4.2	.75	.25	.5	6.7	3.2	4.9	.82	3	.60	7.8	3.2	4.87	.97	.39	.60
	Cl_2 Res. (Free) Cl_2 Res. (Comb.) Cl_2 Res. (Total)	1.0	.2	.5	1.0	.3	.6	1.0	.3	.8	.8	.6	.71	1.0	.5	.88	.7	.4	.55

Note: Where no data printed, data was unavailable.

Table IV-1
Continued

Month	Chemical	1987						1986						1985					
		Pre-			Post-			Pre-			Post-			Pre-			Post-		
		Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
May	Cl_2 Demand Cl_2 Dosage NH_3 SO_2 Cl_2 Res. (Free) Cl_2 Res. (Comb.) Cl_2 Res. (Total)	8.0 1.0	1.8 .2	4.5 .4	.99 1.0	.27 .3	.6 .7	10.1 1.0	2.09 .1	5.38 .6	1.26 .8	.26 .2	.66 .58	9.0 1.0	3.3 .5	6.01 .63	1.1 1.0	0.4 .5	.74 .58
Jun	Cl_2 Demand Cl_2 Dosage NH_3 SO_2 Cl_2 Res. (Free) Cl_2 Res. (Comb.) Cl_2 Res. (Total)	9.0 .8	3.4 .3	5.55 .52	1.1 1.0	.44 .1	.75 .58	6.9 .8	3.2 .4	5.6 .63	.93 .8	.3 .4	.67 .60	10.2 1.0	3.7 .4	7.42 .61	1.2 1.0	.55 .4	.91 .61
Jul	Cl_2 Demand Cl_2 Dosage NH_3 SO_2 Cl_2 Res. (Free) Cl_2 Res. (Comb.) Cl_2 Res. (Total)	10.1 .6	3.2 .2	5.6 – 0.37	1.3 1.0	.38 .3	.72 .67	8.5 1.0	2.2 .3	6.25 .62	1.1 .8	.28 .2	.77 .56	9.3 .8	4.6 .3	7.5 .52	1.2 1.0	.56 .4	.99 .57
Aug	Cl_2 Demand Cl_2 Dosage NH_3 SO_2 Cl_2 Res. (Free) Cl_2 Res. (Comb.) Cl_2 Res. (Total)	9.3 .6	3.1 .3	5.7 .48	1.2 .8	.39 .3	.72 .56	8.3 .8	4.2 .4	5.68 .61	1.0 .8	.52 .3	.70 .56	10.0 1.0	3.9 .2	6.50 .47	1.3 1.0	.48 .3	.78 .50

Note: Where no data is printed, data was unavailable.

Table IV-1
Continued

Month	Chemical	1987						1986						1985					
		Pre-			Post-			Pre-			Post-			Pre-			Post-		
		Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
Sep	Cl_2 Demand																		
	Cl_2 Dosage	11.4	3.2	5.14	1.4	.40	.62	8.3	3.7	5.3	1.0	.45	.66	9.4	3.5	6.36	1.2	.42	.78
	NH_3																		
	SO_2																		
	Cl_2 Res. (Free)																		
	Cl_2 Res. (Comb.)																		
	Cl_2 Res. (Total)	.5	.3	.40	1.0	.4	.73	.8	.4	.61	.9	.2	.58	.8	.4	.54	.8	.3	.61
Oct	Cl_2 Demand																		
	Cl_2 Dosage	10.2	1.4	4.15	1.27	.18	.53	5.9	.35	4.6	.83	.43	0.56	6.1	3.2	4.5	.76	.39	.54
	NH_3																		
	SO_2																		
	Cl_2 Res. (Free)																		
	Cl_2 Res. (Comb.)																		
	Cl_2 Res. (Total)	.7	.1	.45	1.0	.5	.75	.8	.4	.57	.8	.2	.55	.7	.4	.58	1.0	.3	.60
Nov	Cl_2 Demand																		
	Cl_2 Dosage	14.9	2.9	6.47	1.8	.36	.86	5.6	3.1	4.4	.69	.38	.69	5.5	2.5	3.8	.67	.34	.46
	NH_3																		
	SO_2																		
	Cl_2 Res. (Free)																		
	Cl_2 Res. (Comb.)																		
	Cl_2 Res. (Total)	1.0	.3	.59	.8	.4	.68	.8	.4	.55	.8	.3	.58	1.0	.4	.56	1.0	.40	.70
Dec	Cl_2 Demand																		
	Cl_2 Dosage	5.6	.23	3.64	.7	.29	.45	5.9	3.4	4.2	.73	.42	.51	7.5	2.8	4.4	.9	.34	.58
	NH_3																		
	SO_2																		
	Cl_2 Res. (Free)																		
	Cl_2 Res. (Comb.)																		
	Cl_2 Res. (Total)	1.0	.4	.64	1.0	.5	.8	1.5	.4	.72	1.0	.3	.68	1.0	.6	.82	1.0	.5	.66

Note: Where no data is printed, data was unavailable.

Table IV-2
DISINFECTION PROFILE FOR ODESSA WTP

	Pre-Chlorination							Post-Chlorination						
	Cl_2				Residual Cl_2			Cl_2				Residual Cl_2		
Date	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total
Jan/87														
1		6.5							.8					.6
2		3.5				.6			.43					
3		3.5							.43					
4		3.5							.43					
5		5.5				1.0			.67					1.0
6		3.9				.6			.48					.6
7		3.2				.8			.39					.6
8		2.5				.6			.31					.8
9		3.4				.6			.42					.6
10		3.4							.42					
11		3.4							.42					
12		3.7				.6			.47					.6
13		3.1				.6			.39					.6
14		2.8				.6			.35					.6
15		2.7				.6			.34					.6
16		3.6				1.0			.45					.6
17		3.6							.45					
18		3.6							.45					
19		4.3				.6			.54					.6
20		4.1				.4			.52					.5
21		2.5				.8			.32					.7
22		3.3				.8			.41					.6
23		2.8				.6			.35					.4
24		2.8							.35					
25		2.8							.35					
26		2.9				.6			.36					.5
27		2.8				1.0			.35					.6
28		4.7				.8			.58					.6
29		3.5				.8			.44					.9
30		2.6				.6			.31					1.0
31		3.3							.41					

Note: Where no data is printed, no data is available.

Table IV-2
Continued

	Pre-Chlorination							Post-Chlorination						
	Cl_2				Residual Cl_2			Cl_2				Residual Cl_2		
Date	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total
Mar/87														
1														
2		2.7					.5		.33					.5
3		3.3					.4		.41					.4
4		3.7					.6		.45					.6
5		3.7					.6		.46					.5
6		2.6					.7		.32					.5
7		2.6							.32					
8		3.2							.39					
9		4.0					.8		.50					.6
10		3.4					.8		.41					.6
11		2.9					.6		.35					.6
12		2.3					.6		.30					.6
13		2.6					.8		.32					.5
14		2.6							.32					
15		2.6							.32					
16		2.4					.4		.31					.4
17		2.9					.5		.35					.5
18		2.7					.5		.33					.7
19		4.0					.5		.50					.6
20		2.5					.7		.31					.8
21		2.5							.31					
22		2.5							.31					
23		4.5					.85		.56					.7
24		4.9					.7		.61					.6
25		3.3					.2		.41					.5
26		3.9					1.0		.49					.8
27		4.5					1.0		.56					1.0
28		4.5							.56					
29		4.5							.56					
30		5.1					1.0		.63					.6
31		2.3					1.0		.90					.8

Note: Where no data is printed, data was unavailable.

Table IV-2
Continued

	Pre-Chlorination							Post-Chlorination						
	Cl_2				Residual Cl_2			Cl_2				Residual Cl_2		
Date	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total
Jul/87														
1		6.5							.85					
2		3.7				.4			.48					.70
3		6.2				.5			.81					.70
4		6.2							.81					
5		6.1							.81					
6		5.6				.4			.71					1.0
7		5.6				.3			.79					.7
8		5.9				.6			1.2					.8
9		10.1				.6			1.3					1.0
10		6.1				.3			.76					.7
11		6.1							.76					
12		6.1							.76					
13		4.0				.4			.57					.7
14		5.5				.3			.71					.5
15		3.6				.3			.38					.8
16		3.9				.3			.51					.3
17		3.8				.3			.47					.7
18		3.8							.47					
19		3.8							.47					
20		5.4				.4			.67					.7
21		7.0				.3			.87					1.0
22		5.4				.3			.67					.5
23		5.4				.4			.67					.5
24		7.6				.3			.94					.6
25		7.6							.94					
26		7.6							.44					
27		6.5				.3			.80					.5
28		4.3				.3			.54					.4
29		5.4				.3			.67					.4
30		3.8				.4			.47					1.0
31		3.2				.4			.40					.4

Note: Where no data is printed, data was unavailable.

Table IV-2
Continued

	Pre-Chlorination							Post-Chlorination						
	Cl_2				Residual Cl_2			Cl_2				Residual Cl_2		
Date	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total
Oct/87														
1		3.7					.4		.47					.87
2		5.4					.3		.67					.7
3		5.4							.67					
4		5.4							.67					
5		5.9					.4		.73					.8
6		5.4					.4		.67					.8
7		2.2					.4		.25					.7
8		3.2					.4		.38					.7
9		1.4					.4		.18					.8
10		1.4							.18					
11		1.4							.18					
12		1.4							.18					
13		8.6					.3		1.0					.7
14		2.0					.7		.30					1.0
15		1.9					.5		.24					.5
16		1.8					.4		.23					.8
17		1.8							.23					
18		1.8							.23					
19		2.7					.4		.34					.6
20		2.7					.5		.34					.8
21		3.0					.5		.38					.7
22		3.2					.6		.40					.8
23		1.7					.6		.22					.6
24		1.7							.22					
25		1.7							.22					
26		9.6					.1		1.19					.8
27		4.2					.7		.53					1.0
28		7.6					.4		.95					.6
29		10.2					.5		1.27					.5
30		10.1					.5		1.26					.7
31		10.1							1.26					

Note: Where no data is printed, data was unavailable.

Table IV-2
Continued

	Pre-Chlorination							Post-Chlorination						
	Cl_2				Residual Cl_2			Cl_2				Residual Cl_2		
Date	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total
Jan/86														
1		4.9							.61					
2		7.2				.6			.88					.8
3		5.7				.7			.62					.4
4		5.7							.62					
5		5.7							.62					
6		5.0				.6			.62					.6
7		4.2				.6			.51					.7
8		5.3				.6			.65					.6
9		4.9				.7			.60					.4
10		4.2				.6			.52					.6
11		4.2							.52					
12		4.2							.52					
13		4.8				.8			.59					.8
14		5.1				.6			.63					.3
15		5.4				.6			.66					.6
16		5.2				.7			.63					.6
17		5.6				6			.68					.6
18		5.6							.68					
19		5.6							.68					
20		5.7				.6			.70					.6
21		5.9				.8			.72					.8
22		4.0				.5			.49					.5
23		3.2				.6			.39					.6
24		3.8				.5			.47					.5
25		3.8							.47					
26		3.8							.47					
27		4.6				.8			.45					.8
28		4.6				.6			.56					.6
29		7.5				.8			.92					.8
30		5.3				.6			.65					.6
31		3.9				.6			.48					.6

Note: Where no data is printed, data was unavailable.

Table IV-2
Continued

	Pre-Chlorination							Post-Chlorination						
	Cl_2				Residual Cl_2			Cl_2				Residual Cl_2		
Date	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total
Mar/86														
1		4.3							.53					
2		4.3							.53					
3		3.9				.8			.48					.75
4		4.1				.8			.51					.60
5		3.1				1.0			.38					.70
6		3.7				.8			.47					.60
7		3.4				.8			.42					.60
8		3.4							.42					
9		3.4							.42					
10		4.1				.8			.51					6.0
11		4.8				.8			.59					6.0
12		4.8				.7			.55					4.0
13		4.1				.5			.51					6.0
14		6.4				.6			.79					5.0
15		6.4							.79					
16		6.4							.79					
17		5.1				.8			.62					6.0
18		5.3				.8			.64					6.0
19		6.0				1.0			.74					8.0
20		7.3				.8			.90					6.0
21		5.6				1.0			.69					8.0
22		5.6							.69					
23		5.6							.69					
24		3.0				.8			.37					6.0
25		3.9				.8			.46					6.0
26		3.7				1.0			.45					6.0
27		4.4				.8			.54					6.0
28		4.4							.54					
29		4.7							.56					
30		4.7							.56					
31		4.7							.56					

Note: Where no data is printed, data was unavailable.

Table IV-2
Continued

	Pre-Chlorination							Post-Chlorination						
	Cl_2				Residual Cl_2			Cl_2				Residual Cl_2		
Date	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total
Jul/86														
1	6.5								.78					
2	7.5					.6			.92					.6
3	4.1					.6			.51					.6
4	6.2					.6			.77					.8
5	6.2								.77					
6	6.2								.77					
7	4.1					.8			.8					.8
8	5.3					.6			.8					.8
9	4.8					.8			.8					.8
10	4.4					.6			.5					.5
11	6.5					.6			.8					.8
12	6.5													
13	6.5													
14	4.9					.6			.6					.6
15	6.8					.4			.6					.6
16	5.4					.8			.6					.8
17	8.5					.5			.5					.5
18	8.3					.7			.3					.7
19	8.3													
20	8.3													
21	5.6					.5			.5					.5
22	5.4					.5			.6					.6
23	9.5					.6			.6					.6
24	9.1					1.0			.8					.8
25	5.7					1.0			.6					.6
26	5.7													
27	5.7													
28	2.3					.3			.2					.2
29	4.3					.5			.2					.2
30	7.8					.4			.3					.3
31	7.4					.7			.3					.3

Note: Where no data is printed, data was unavailable.

Table IV-2
Continued

Date	Pre-Chlorination							Post-Chlorination						
	Cl_2				Residual Cl_2			Cl_2				Residual Cl_2		
	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total
Oct/86														
1		5.3					.6		.65					.4
2		4.6					.4		.57					.3
3		6.8					.4		.83					.2
4		6.4					.5		.78					.3
5		6.4							.78					
6		5.9					.7		.72					.8
7		5.9					.6		.67					.6
8		3.8					.8		.48					.8
9		4.8					.8		.60					.5
10		4.3					.7		.54					.2
11		4.3							.54					
12		4.3							.54					
13		4.3							.54					
14		5.4					.4		.66					.6
15		4.0					.6		.50					.6
16		4.6					.5		.57					.6
17		3.7					.6		.45					.6
18		3.7							.45					
19		3.7							.45					
20		4.1					.6		.51					.6
21		5.6					.5		.68					.7
22		4.2					.6		.52					.6
23		4.0					.6		.50					.6
24		3.8					.6		.46					.6
25		3.8							.46					
26		3.8							.46					
27		3.8					.5		.46					.6
28		4.3					.6		.53					.6
29		4.1					.5		.51					.8
30		3.5					.6		.43					.6
31		4.3					.6		.53					.6

Note: Where no data is printed, data was unavailable.

Table IV-2
Continued

	Pre-Chlorination							Post-Chlorination						
	Cl_2				Residual Cl_2			Cl_2				Residual Cl_2		
Date	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total
Jan/85														
1		5.4							.67					
2		5.3					1.0		.65					.5
3		5.4					1.0		.67					1.0
4		5.5					1.0		.69					.6
5		5.5							.69					
6		5.5							.69					
7		5.3					1.0		.66					1.0
8		5.5					1.0		.68					1.0
9		3.5					1.0		.43					.8
10		4.5					1.0		.56					.6
11		5.2					1.0		.65					.5
12		5.2							.65					
13		5.2							.65					
14		5.1					1.0		.64					1.0
15		7.0					1.5		.88					.5
16		6.8					1.1		.86					.5
17		6.1					1.0		.77					.4
18		4.3					1.0		.53					.5
19		4.3							.53					
20		4.3							.53					
21		5.6					1.0		.71					.7
22		7.4					1.0		.94					.5
23		5.8					1.0		.73					1.0
24		6.6					1.0		.84					.8
25		3.3					1.0		.41					.8
26		3.3							.41					
27		3.3							.41					
28		4.4					.6		.59					.5
29		4.4					.3		.59					.5
30		6.4					.5		.81					.6
31		6.5					.6		.79					.8

Note: Where no data is printed, data was unavailable.

Table IV-2
Continued

	Pre-Chlorination							Post-Chlorination						
	Cl_2				Residual Cl_2			Cl_2				Residual Cl_2		
Date	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total
Mar/85														
1		6.36					1.0		.79					0.5
2		9.18					1.0		1.1					0.5
3		9.18					1.0		1.1					0.7
4		7.6					1.0		.93					0.5
5		5.4					1.0		.66					0.5
6		6.6					1.0		.81					0.9
7		4.0					1.0		.49					0.9
8		2.6					1.0		.32					1.0
9		2.7					.8		.33					0.5
10		2.7							.33					0.8
11		3.5					1.0		.43					1.0
12		2.8					.5		.34					0.8
13		3.7					.7		.46					0.6
14		4.1					1.0		.50					0.8
15		4.1					1.0		.50					0.4
16		4.1							.50					
17		4.1							.50					
18		4.8					1.0		.59					0.4
19		3.6					1.0		.45					0.4
20		5.2					1.0		.64					0.5
21		3.4					1.0		.42					0.5
22		4.2					1.0		.52					0.5
23		4.2							.52					
24		4.2							.52					
25		4.8					1.0		.59					.06
26		4.6					1.0		.56					.06
27		5.1					1.0		.63					0.6
28		5.6					1.0		.69					0.6
29		6.0					1.0		.74					0.6
30		6.0							.74					
31		6.0							.74					

Note: Where no data is printed, data was unavailable.

Table IV-2
Continued

	Pre-Chlorination							Post-Chlorination						
	Cl_2				Residual Cl_2			Cl_2				Residual Cl_2		
Date	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total
Jul/85														
1		7.4							.92					
2		8.5				.5			1.0				.5	
3		8.0				.6			1.0				.6	
4		5.8				.6			.71				.4	
5		7.2				.4			.90				.6	
6		7.2							.90					
7		7.2							.90					
8		7.6				.4			.93				.5	
9		5.5				.3			.68				.5	
10		6.7				.5			.83				.5	
11		4.6				.5			.56				.5	
12		7.4				.5			.86				.5	
13		7.4							.86					
14		7.4							.86					
15		6.3				.4			.78				.6	
16		4.8				.4			.59				.6	
17		6.4				.6			.78				.6	
18		8.0				.6			.59				.6	
19		9.3				.6			1.2				.6	
20		9.3							1.2					
21		9.3							1.2					
22		6.8				.4			.84				.4	
23		7.8				.5			.97				.6	
24		9.2				.6			1.1				.7	
25		8.9				.6			1.1				.7	
26		8.2				.6			1.2				.6	
27		8.2							1.2					
28		8.2							1.2					
29		7.8				.7			.96				.5	
30		8.2				.8			1.0				.4	
31		8.0				.4			1.0				1.0	

Note: Where no data is printed, data was unavailable.

Table IV-2
Continued

	Pre-Chlorination							Post-Chlorination						
	Cl_2				Residual Cl_2			Cl_2				Residual Cl_2		
Date	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total	Dem.	Dos.	NH_3	SO_2	Free	Comb.	Total
Oct/85														
1		5.1					.5		.6					.7
2		6.1					.5		.8					.6
3		4.9					.4		.6					.7
4		3.3					.6		.4					.6
5		3.3							.4					
6		3.7							.5					
7		4.1					.7		.5					.5
8		4.6					.6		.6					.5
9		4.3					.6		.5					.4
10		4.6					.7		.5					.3
11		4.8					.6		.6					.4
12		4.8							.6					
13		4.8							.6					
14		4.2					.7		.5					.3
15		4.2					.7		.5					.5
16		5.3					.5		.7					.5
17		5.8					.5		.7					.7
18		3.8					.6		.5					.5
19		4.0							.5					
20		4.0							.5					
21		4.0					.5		.5					.7
22		4.8					.6		.6					.6
23		4.9					.6		.6					.6
24		4.5					.7		.6					.8
25		5.0					.6		.6					.6
26		4.7							.6					
27		4.7							.6					
28		4.7					.5		.6					.8
29		5.2					.6		.6					.7
30		4.5					.5		.6					1.0
31		3.2					.6		.4					1.0

Note: Where no data is printed, data was unavailable.

Appendix V

JAR TESTING PROTOCOL

EXPERIMENTAL PROTOCOL FOR JAR TESTING

APPARATUS

The apparatus consisted of a Phipps & Bird, Inc. 6-place stirring apparatus. Two litre gator jars were used as the reaction vessels since they have been shown to provide a more realistic mixing environment than the usual 1 L round beakers which are commonly used in these types of evaluation. The root-mean-square velocity gradient was based on the calibration reported by Cornwell and Bishop (1983).

Final pH was determined using a Fisher Accumet 915 pH meter. Turbifity was measured using a Turner Designs Model 40 Nephelometer with a 2.0 NTU formazin standard. Total and dissolved organic carbon (TOC and DOC) were determined later by CANVIRO Analytical Laboratories. The organic carbon samples were preserved and stored in accordance with Standard Methods (1985).

REAGENTS

Alum - liquid alum from the Deseronto WTP was diluted to provide a stock solution containing 50 mg/L of $AL_2 (SO_4)_3 . 14.2 H_2O$.

Polyelectrolyte - a prepared 0.15% solution of Aquafloc 6465 was obtained from the day tank at the Deseronto WTP.

Bentonite - a 5% solution was obtained from the day tank at the Odessa WTP. This was diluted to provide a stock solution of 5 mg/mL.

PROCEDURE

1. A 40 L grab samples was obtained from the raw water line to ensure that all of the trials used the same water.

2. Two litres of raw water was added to each gator jar. The gator jars were numbered according to the jar numbers in Table 1 and the treatment combination for the jar was noted on each jar.

3. The rapid mixing Gt was 36,000 (100 RPM for 360 s).

4. The flocculation Gt was 12,000 (30 RPM for 600 s).

5. Sedimentation time was 20 min.

6. The treatment combinations were chosen randomly and the appropriate jars were placed on the stirring apparatus. At the start of the experiment, all of the reagents were added as quickly as possible to the jars. The time span was approximately 90 s from the first to last jar.

7. At the end of the sedimental period, approximately 125 mL of sample were obtained for immediate turbidity and pH determinations. A further 250 mL were obtained for future TOC and DOC determinations.

8. During the flocculation and sedimentation periods, the jars were observed and the appearance of the floc was noted.

9. A qualitative evaluation of the strength of the various flocs was performed by simulating a hydraulic surge in the gator jars by briefly accelerating the stirrer to excite the settled flocs and then observing which ones settled the best afterwards.